

KEEPING COOL

AND OTHER ESSAYS

By

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MAHARAJA COLLEGE
SRINAGAR

LONDON

CHATTO & WINDUS

1940

By the same Author

POSSIBLE WORLDS AND OTHER ESSAYS

THE INEQUALITY OF MAN AND OTHER ESSAYS

THE CAUSES OF EVOLUTION

ENZYMES

DAEDALUS, OR SCIENCE AND THE FUTURE

CALLINICUS, A DEFENCE OF CHEMICAL WARFARE

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MY FRIEND MR. LEAKEY

ANIMAL BIOLOGY ; with J. S. Huxley

A.R.P.

SCIENCE AND EVERYDAY LIFE

HEREDITY AND POLITICS

THE MARXIST PHILOSOPHY AND THE SCIENCES

PRINTED IN GREAT BRITAIN BY
BUTLER AND TANNER LTD.
FROME AND LONDON

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PREFACE

THESE essays have appeared during the last seven years in a variety of journals, and in some collections of essays by various authors. Four of them were broadcast and two were given as lectures. They are by-products of my other activities, namely, scientific teaching and research, and, since 1936, political work. I sometimes envy my colleagues who contrived to live in little worlds of their own, cut off from the big world. Or rather who contrived to think that they did so, for at the time of writing this preface, in the first week of September 1939, they can hardly continue to hold this view. I have never held it, but since I began to study the application of scientific method to the development of societies, I have certainly felt more justified in my attempts to popularize all kinds of science.

I write this in London, waiting to be bombed, but refusing to believe that even if Western Europe is seriously damaged, this will spell the end of civilization, or prove the danger of scientific knowledge. On the contrary, I believe that we need more science, not less, and science applied not only to certain branches of production, destruction, and medicine, but to human life as a whole. In this firm conviction I dedicate this book to readers who know enough history to realize that history is a record of pretty nasty facts, and that in spite of this, human culture, including science, has advanced and will continue to advance.

J. B. S. HALDANE.

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UNSOLVED PROBLEMS OF SCIENCE

I. Weather

IF you buy a textbook of science, or learn it at school or at a university, you will be presented with the solutions of problems. You will be told how to calculate the force exerted by a magnet, or what is the cause of typhoid fever. But if you attend a meeting of a scientific society you will hear about the unsolved problems. Its members will be discussing the forces acting on the Milky Way, or the cause of cancer.

In this series of chapters* I want to take my readers behind the scenes, to let them know what sort of questions interest scientists and occupy their thoughts. Many people think that scientists should be ashamed of the very existence of these problems, that we ought to know our business by now, and that if we have so far failed, the search should be handed over to someone else, to spiritualists or herbalists, Christian Socialists or Mr. Bernard Shaw. This is not quite fair, for a simple reason. Every scientific problem solved gives us a number of new ones to puzzle us. Sir Humphry Davy found that common salt was made of a soft metal, sodium, and a green gas, chlorine. A great discovery, but it meant that chemists now had to study sodium and chlorine, as well as salt. Pasteur found that many diseases were caused by bacteria. His successors were left to find out how bacteria live, what they eat, how they breed, and how best to kill them.

* Published in the *Sunday Chronicle*.

I am going to begin with the one scientific problem which interests every man every day—the problem of weather. We can forecast it for a day or two ahead, but that is all. We cannot tell a week ahead whether it is going to rain on August Bank Holiday. Above all, we can say almost nothing about the weather twenty years or two thousand years ahead. Yet the whole future of our country depends on the weather. In the past there have been big changes in the weather, lasting over centuries and moulding human history. Between A.D. 450 and 1000 the weather was much warmer and drier than it is now. During that time the Northmen constantly invaded England. The North Sea was generally calm, and their voyages were easy. What is more, they rowed across the North Atlantic to Greenland, which really was green in those days, and even to Canada.

If we get a few centuries of really good weather in the future, Canada will become one of the world's greatest nations, with a population of hundreds of millions, and wheat-fields stretching up to the Arctic circle. There will be no more icebergs in the North Atlantic, and all through the year ships will use the great ports which will be built round Hudson Bay.

But the weather may equally well get worse. Two thousand years ago England was so wet that the valleys were full of great swamps, and the chalk uplands of Salisbury Plain were the most habitable parts of the country.

In the past such changes of weather meant the end of great civilizations. Some scientists believe that the highest forms of civilization have only been able to flourish where the weather was not too extreme, as regards heat or cold, moisture or drought, and where it was changeable enough to be stimulating. This may have

been true in the past, when people spent most of their lives out of doors. But to-day we English live mainly indoors, in an artificial climate of our own making, which is probably altering our national character. So an urban civilization would be able to stand up to a climatic change which might have wiped out a civilization based on agriculture.

Finally we may have a real cold spell. Everyone knows that thirty thousand years ago most of England and Canada were covered with ice. The ice moved southward with such force that blocks of rock from Norway are found scattered all over Norfolk, and the village of Great Catworth in Huntingdon is mostly built on a huge lump of chalk torn from the Lincolnshire Wolds.

A generation ago scientists talked of the great Ice Age. It was over, they said, and there was no reason to expect another. But since then rather an alarming discovery has been made. There was not one ice age, but there were four, separated by warmer periods. If there have been four, there seems no reason whatever why there should not be a fifth.

It is worth while picturing what that will mean. Most of England will be covered with ice, which will grind every vestige of civilization out of existence. A few cairns on the top of the highest hills, and the mud-filled shafts of our mines, will be all that remains to show that northern England and Scotland had ever been inhabited.

The South Coast will probably be kept free by warm currents, as it was during former ice ages. The glaciers never got south of the Thames. So southern England will be a snowy country inhabited by a few fur trappers. For the clouds which now fertilize England will go farther south, and shed their rain on what is now the

Sahara Desert. And the fashionable ladies of Timbuctoo will doubtless demand real English arctic foxes. Perhaps, however, a few enterprising Saharan tourists will occasionally venture so far north, and ski among the ruins of London.

On the other side of the Atlantic the ice will come a good deal farther south. The advancing glaciers will sweep aside the proud skyscrapers of New York as a broom sweeps away autumn leaves. Canada will be as desolate as Antarctica to-day. Occasional bold airmen flying across it will say, 'There used to be a city called Montreal somewhere near here. But of course there are no landmarks on this ice, and we can't tell the site within ten miles.'

These events sound dramatic enough. But if they happen they will not be particularly dramatic because of the extreme slowness of geological as compared with human happenings. We do not know how quickly the ice advanced during the last ice age. We do know how slowly it retreated. When the great ice-sheets that covered Canada and Scandinavia were melting there was a flood every spring which laid down a sheet of mud. These sheets have been counted, and we know that the site of Stockholm was uncovered less than twelve thousand years ago, and that on the average the ice in southern Sweden retreated at the rate of only about two hundred yards per year.

So if an ice age begins next year it will be several thousand years before England is covered with ice. The first signs would probably be a series of very snowy winters and cloudy summers. The snow on the Scottish Highlands would last late into the spring, and then throughout the year. There would be a boom in winter sports in Scotland. Within a century a few small glaciers

would be forming on the northern sides of some of the Scottish mountains, and all over the world the existing glaciers would be pushing their way downwards.

But there would be few headlines. The northern lands and Switzerland would be gradually abandoned. Centuries before any town was overwhelmed by the ice it would have been quietly evacuated owing to the cold, and have become a mere name in the history books. To-day no one but archaeologists would care if the desert sands covered the mounds that were once Babylon and Nineveh. If the ice ever covers London and New York again a few African or Mexican schoolmasters may bore their classes with accounts of the quaint people who once lived there. But the ordinary man and woman will probably never hear of it.

Another ice age, if it happens, will certainly not wipe out civilization. Civilization will retreat southwards, as the men of the old stone age retreated before the last ice-sheet. And when the ice melts after fifty or a hundred thousand years our descendants will return to re-people the waste lands.

Just because it will not be dramatic, like a flood or an earthquake, it is quite likely that men will do nothing to fight against another ice age. At the present time they could do nothing about it if they wanted to. But if our civilization lasts for another few centuries the means of producing enough energy to melt an ice-field may be at man's disposal. It does not follow that it will be used. For a worse climate in the north would mean a better climate in the south. Provided there is some kind of civilization five thousand years hence I don't care if it is centred round London or Timbuctoo, and I would not go without my motor-car to save England from the ice

and keep the Sahara Desert dry. So if there is going to be another ice age I doubt if any attempt will be made to stop it.

Fortunately such gloomy prophecies as the above have a happy ending. There is no question of a permanent ice age. There may be one more or a dozen more, but they will come to an end. During almost all geological time we know from the evidence of fossils that the weather was far better than it is now. There was no ice even in the Arctic. Greenland and Antarctica were covered with vegetation.

Before the present series of ice ages there had been several earlier series, probably at least four. The last one was about two hundred million years ago, long before the age of the giant reptiles, and since then there were no ice-fields till less than a million years past. A series of ice ages is a malady from which our planet occasionally suffers, just as a man a few times in his life gets a disease which gives him several bouts of fever.

When our planet finally gets over its present chill and settles down to good weather, the ice-caps on Greenland and Antarctica will melt, and men will live in these countries. Just as explorers in the Sahara ride over the ruins of ancient towns buried beneath the sand, so arctic and antarctic explorers run their sledges over the sites of cities which their remote descendants will inhabit, sites which are now hidden under an ice-sheet which may be a mile thick.

Even if we knew the cause of the former ice ages, we might not be able to tell whether there will be another. But we do not know their cause. There are plenty of theories. Some scientists think that the sun gave less heat, others that it gave more, in consequence

of which more water was evaporated from the sea, the whole air became cloudy, and so much snow fell that great glaciers spread southwards. Another theory is that there was less carbon dioxide in the air, so that the earth cooled down much quicker at night. Others again think that the earth's crust slipped on its core, so that the North Pole was in Greenland. That is only a small sample of the theories.

At this the plain man may fairly say, 'Scientists must have a nice easy time making theories about ice ages. They can't be tested till the next one comes, by which time their makers will have been dead for centuries.' Luckily there is a perfectly good answer to this criticism. No scientific theory is worth anything unless it enables us to predict something which is actually going on. Until that is done, theories are a mere game with words, and not such a good game as poetry. These theories can and will be tested. If the North Pole shifted to Greenland, Siberia must have been warmer when Europe and North America were colder. If there was less carbon dioxide in the air, plants must have grown more slowly.

We can apply this simple test to any problem which we are asked to solve. There is an old problem which has been solved, though people still sometimes ask it. 'Which came first, birds or eggs?' The answer is, 'Eggs.' Birds were descended from reptiles which laid eggs. Wherever you choose to draw the line between birds and reptiles, it is sure that the first bird hatched out of an egg.

And the answer to this problem is of real practical value. We know roughly when the first birds appeared. It was about the time when the Bath limestone and the Oxford clay were being formed on the sea-bed, long after the age of coal, but before that of chalk.

This means that if we find a fossil feather we can be sure that the rock in which it is found was laid down long after the coal measures. So there is at least a chance that there may be coal underneath it. Almost the only way that we have of dating rocks is by the fossils in them. There are still a number of people who do not believe in the theory of evolution. Scientists believe in it, not because it is an attractive theory, but because it enables them to make predictions which come true. If only the critics of evolution had the courage of their convictions they would start mining for coal in Cornwall or tin in Oxfordshire.

The different branches of science are so linked up that we cannot tell how they will affect one another. My father invented an apparatus for air analysis in order to test the air in schools, factories, and mines. If the carbon dioxide rises above a certain level this is a sign that better ventilation is needed. Just before he died he managed to make this apparatus ten times more sensitive, so that one can follow the changes in the carbon dioxide of outside air, of which there is about an ounce in fifty cubic yards.

If the theory that great weather changes are due to changes in the carbon dioxide is true, this apparatus will enable us to test it. I think the odds are against this particular theory, but it would not be at all surprising if a research on stuffy schoolrooms led to a means of predicting and perhaps even preventing an ice age.

Pasteur started out to find why certain crystals are lopsided, and ended up by discovering the bacteria which cause diseases. It is the glorious uncertainty of what our discoveries may mean for the future which makes scientific research a gamble even more fascinating than horse-racing or politics.

UNSOLVED PROBLEMS OF SCIENCE

II. Under Our Feet

ANYONE except a prisoner can go and see what things are like ten miles north, east, south, or west. If he is rich enough he can hire a balloon and go ten miles up. But no one has ever been even two, let alone ten, miles below the earth's surface.

At the present moment our imagination is turned upwards. For every hundred men who could tell me the height record of the human race, hardly one could tell me its depth records either under the earth or under the sea. And yet this upward record-breaking contributes neither to wealth, power, nor knowledge. There are no minerals in the air, and England's wealth comes mainly from underground. There is no value even for war purposes in flying above six miles. There is no knowledge to be gained which could not be gained by sending up apparatus in unmanned balloons.

Perhaps after the next war* things will alter. The survivors will be accustomed to living in burrows. They will look up to the sky with horror, and enjoy the thought of a few hundred feet of solid rock above their heads. If so they will probably want to know what is below them, to explore the inside of the earth as their forefathers explored its outside.

We know a little about the inside of the earth, but our knowledge is tantalizingly scrappy. First of all it is very hot. As we go down the rocks get progressively hotter.

* Now started.

In English mines a mile or so deep the men work in bathing-drawers, and I have seen them emptying the sweat out of their boots when they stopped work for lunch.

For every mile that we go down the rock temperature rises about 90° F. in Europe, though rather more slowly in South Africa; but of course ventilation keeps the air in mines cooler than the rocks. This means that two miles down, the rocks are at the boiling-point of water, while ten or fifteen miles down they are red-hot. The Lancashire coalminers explain the matter simply. They say they are getting near hell.

The pressure rises with the temperature. At a depth of a mile the rock above the miner weighs over thirty tons per square inch. And this pressure acts in all directions. If we go down a deep mine which has been abandoned for a month or two during a strike we find that not merely has the roof begun to cave in, but the floor has bulged up. So a shaft ten miles deep would have to be protected against the rock pressure by lining it with armour plate many feet in thickness. Otherwise the rocks would flow inwards like so much butter.

It is generally agreed that at a great enough depth the interior of the earth is liquid. Every solid substance when hot enough becomes a gas, and most of them pass through a liquid phase first. But both melting and boiling are usually checked by high pressure, so it is hard to be sure whether heat or pressure will predominate inside the earth.

As everyone knows, molten lava sometimes pours out of volcanoes. Can we take it as a fair sample of what we should meet if we went down deep enough? Underneath its thin skin is the earth solid or liquid? This problem is only partly solved. There are two answers which seem to be contradictory.

The first answer comes from the study of gravity. If a plumb-line is held near the foot of a cliff, the bob is pulled away from the vertical by the attraction of the cliff. It was expected that mountain ranges would act in the same way. But they do not. Often the bob seems to be pushed away from them. This is because they are made of lighter material than the rest of the earth's crust. Their density can also be measured in other ways, all of which give the same result.

Mountain ranges stick up because they are made of light rock. The ocean floor is low because it is made of heavy rock. In simple language, the earth's crust consists of slag floating on hell-fire. When a load is taken off, the surface rises. The Alps were originally a plateau only about four thousand feet high. When the rain and ice cut valleys in it, some of the weight was taken off the supporting liquid, and the crust bulged up to make the present peaks.

This bulging is sometimes a slow process. Scandinavia was still covered by a sheet of ice fourteen thousand years ago. It was almost all melted by 7000 B.C. The crust had sagged under the strain, and is still rising, in some places by half an inch per year. Unfortunately from time to time rocks may snap, and we get earthquakes. However, the quakes due to this cause are much milder than those due to folding.

The solid crust is about forty miles thick: more in some places, and much less in volcanic regions. But the underlying layer, though it yields to slow pressure, does not seem to be a genuine liquid. The evidence is as follows. When a great earthquake occurs anywhere, the shock is recorded by instruments all over the world. The first wave caused by an earthquake in New Zealand takes about twenty minutes to reach England.

Now when we can study waves which go through anything we learn a great deal about it. For example, we know that the upper air lets light waves through but reflects most radio waves back, and this allows us, among other things, to calculate its temperature, which is rather high. A solid will transmit two sorts of waves, namely, push waves, where the particles move along the line of travel, and shake waves, where they move sideways. A true liquid will only transmit push waves. If you raise the pressure at one end of a pipe full of water you can transmit the push to the other end, but if you turn the water round you cannot transmit the twist, as you could with a solid rod.

The radius of the earth is four thousand miles. The inner core for two thousand miles out from the centre is a true liquid and will not transmit shake waves. It probably consists of liquid iron, so hot that if the pressure above it were taken off, it would fly apart as gas. For two thousand miles between the iron and the solid crust is a layer of rock which is solid enough to carry shake waves, but not solid enough to bear the weight of mountain ranges, or even ice-fields, indefinitely.

Lava is liquid because the pressure has been taken off it, but under heavy pressure, even when very hot, it is so stiff as to have many of the properties of a solid. Our knowledge of these matters mostly comes from American workers. Some of them worked in Hawaii, pushing down steel tubes into the lakes of lava of its great volcanoes, taking temperatures and analysing the molten rock at different depths.

Others, in Washington, worked in the laboratory with what might be called artificial volcanoes. It is easy enough to subject any material to very high tempera-

tures. You have only to put it into the arc of an ordinary arc-lamp. And in special presses, pressures of a hundred thousand atmospheres have been reached.

But the combination of the two was not so easy. Bombs were built of vanadium-containing steel such as is used for the armour of battleships. Inside the bomb an electric furnace heated up small fragments of rock enclosed in platinum capsules. Pressures corresponding to those found many miles below ground were meanwhile applied, the bombs being filled with liquid carbon dioxide.

These bombs occasionally burst, and the fact that their contents were white-hot did not make things any pleasanter. In fact, the real volcanoes of Hawaii were perhaps rather safer than the artificial ones at Washington. But the latter did serve to explain how the real ones worked. Among other things it was found that white-hot rock would dissolve a great deal of water at high pressure. When the pressure was taken off the water separated out, and finally became steam, thus accounting for volcanic explosions.

Other experiments showed how mineral ores were formed. When melted rock cools down, some parts solidify before others, just as the oily part of gravy congeals before the watery part. In some kinds of molten rock the valuable minerals separate first and sink to the bottom; in others they stay liquid for a long time, and rise to the top. By such experiments the actual distribution of ores in the earth is beginning to be understood. Laboratory experiments show why in Cornwall the quartz veins contain copper at the top and tin lower down.

But this whole branch of science is in its infancy. Experiments are costly and sometimes dangerous. They

enable us to predict to a certain extent what we shall find underground, but not exactly. In the long run we shall have to go down and find out. Let us suppose that a state, or a really enterprising millionaire, has put down £20,000,000 or so to sink a shaft ten or twenty miles deep, what would be the first step?

Naturally we would not choose a country liable to earthquakes or natural volcanoes. There would not be much advantage in simply making another volcano. But the first step would be to make an artificial earthquake. The best artificial earthquake so far was at Oppau in Germany, where 4,500 tons of explosive accidentally went off in 1921. The earthquake was recorded, and gave information about the various kinds of rock under Germany.

The most usual finding is a mile or so of sedimentary rocks laid down in water, then six or eight miles of granite, which has solidified from the molten state, and below this several layers of denser rock of the general nature of basalt. Special laboratories would be built to test the behaviour of the rocks under high pressure and temperature, so that the miners would know what to expect.

After the first mile or two there would be little chance of striking coal or oil, but metals and precious stones might well be found if the shaft was sunk in a suitable area. We do not know how diamonds are formed, but we know that they can only be formed at enormous pressures and temperatures. The South African diamonds occur in 'pipes' full of a peculiar blue volcanic rock which has come up from a great depth. A sufficiently deep mine might yield diamonds in enormous quantity.*

* Some of the physicists who have studied earthquakes think that there is a shell of the kind of rock in which diamonds are found at a depth of about twenty miles.

But it is just as likely that these stones may be made artificially as a by-product of an experiment in artificial vulcanism.

The one thing which will certainly be found is heat. Before the shaft is two miles deep special cooling arrangements will be needed. Probably liquid air will be sent down a pipe to cool the workings. Where the red-hot layer is reached the shaft will become a possible source of power. If two shafts fifteen miles deep were connected by a tunnel (armour-plated, of course), a river dropped down one of them would come up the other as steam, and would be a very considerable source of power. In a century or so, when the world's supply of oil has run out and coal is getting a good deal scarcer, power may be worth a good deal more than it is to-day.

Whether it pays or not, we shall have to explore the first forty miles of our planet's crust, the truly solid part. And we shall do it if science goes on. The result may be of as little economic value as the exploration of Antarctica, or it may pay as well as the exploration of Canada. It may make gold as plentiful as copper, which would merely wreck our monetary systems, or diamonds as cheap as tin, in which case we should use them for a great variety of cutting tools, for the bearings of machinery, and for microscope lenses. It may merely clear up a few doubtful scientific points.

Human curiosity will not be satisfied until we have got to the earth's centre. I cannot imagine how this would even be attempted, but I certainly cannot say that it is impossible. It will not be easy or safe, but miners are as brave as airmen, and when we begin to run short of some essential minerals we shall turn our eyes downwards, and begin the exploration of the unknown depths below us.

UNSOLVED PROBLEMS OF SCIENCE

III. Inside the Sun

IF you go to a meeting of the Royal Astronomical Society you will find the atmosphere on the whole peaceful. The Astronomer Royal does not rise in his place to denounce astrology. The moon may turn up a second late at an eclipse without causing any real scandal. But discussions about the inside of the sun or any other star are always heated. And appropriately so, for they refer to the hottest things in the universe.

This might well be regarded as the supreme example of scientific futility, for the inside of the sun is entirely inaccessible. But there are two reasons why it is not futile. The sun is the direct or indirect source of all our energy. The energy of our muscles is mostly sunlight stored by wheat or potato plants. Our fires are driven by the sunlight caught by the mosses and ferns of the coal measures two hundred million years ago. Wind and water-power too are only second-hand sunlight.

So the problems of where this energy comes from and how it is made are quite fundamental. A generation ago it was thought that the sun could not have shone for more than twenty million years or so without getting cold. If that were so, Darwinism would have been a very improbable theory. Men could hardly have evolved from fish in so short a time.

The other reason is that the investigation of the sun's outside was a highly practical proposition. When physicists first broke up the sun's white light into its

component colours with a spectroscope they did not find quite all the colours of the rainbow. There were a number of dark lines in the spectrum, as a rainbow is called when accurately focussed. An electric lamp gives a spectrum with no dark lines, but if we pass the light through hot vapour each element stops light of a particular sort, and leaves its mark in the form of dark lines.

In a flame or an electric discharge the vapour of an element shines with light of the same kind as it absorbs. Its spectrum is its signature tune, so to speak, telling us about how its atoms behave. The signature tunes of many well-known elements were found in the sun. Among them was one belonging to an unknown composer. This hypothetical element was christened helium. Twenty-seven years later it was found on earth, where it is almost as rare as it is common in the sun. It turned out to be a light, non-inflammable gas, and is indispensable for airships, as the only alternative, hydrogen, burns very readily. Modern chemistry is largely founded on the study of spectra. A full knowledge of an element's spectrum enables you to calculate its chemical reactions, and many inventions, including neon lamps and the hottest known flames, have arisen indirectly from the study of the sun's outside.

Very gradually astronomers found out the conditions in the layer of the sun from which its light comes. It consists of a mixture of gases at a temperature of ten thousand degrees Fahrenheit and a pressure of about a thousandth of an atmosphere, corresponding to that of air thirty or forty miles above the earth.

The sun's surface is pouring out energy at the rate of sixty horse-power per square inch. It has been doing so

at much the same speed for at least a thousand million years, for even so long ago there were occasional ice ages on the earth, which shows that the sun was not much hotter than it is now.

If the sun consisted of solid coal, it would burn away completely in ten thousand years at this rate of heat production. Clearly we must look for some entirely different source immensely more powerful than chemical reactions.

It is far easier to calculate what things are like inside the sun than inside the earth, for two reasons. The sun consists of gas, and the properties of gases are much simpler than those of solids. Also a great many of them are the same for all gases.

Still, long before they get to the middle of the sun, mathematicians are at loggerheads. One group puts the central temperature at or about ten million degrees, the other in thousands of millions. These groups, who may be called the 'colds' and the 'hots', have adherents in all civilized countries, who argue with one another in the most terrific mathematical formulae.

Any theory about the sun has got to explain where its heat comes from. If at these high temperatures matter gives off heat in enormous amounts, then the sun ceases to be mysterious. Now we cannot get temperatures of even ten thousand degrees in the laboratory, let alone a thousand million. But we can see how matter behaves at these temperatures.

At a thousand million degrees the atoms in a gas are moving eighteen hundred times as fast as they move at ordinary temperatures, and constantly colliding with one another. If electrically charged gas atoms are put in an electric field they can be given very high speeds, and

when they run into something solid we can see what an atomic collision at such speed means.

It was only in 1932 that two Cambridge workers, Cockcroft and Walton, got atoms moving at speeds corresponding to those found inside the sun on the 'hot' theory. They found that the collisions were so violent as to alter the atoms, and make one chemical element out of another, which is of course quite impossible at an ordinary temperature.

And some of these transformations gave out energy on a scale many thousands of times greater than any chemical reaction. It has at last been possible to copy in the laboratory the sun's way of making energy, even if we are not yet sure of the exact processes which go on inside the sun.

It would have been very awkward for science if nothing had happened to these high-speed atoms. It would have left the source of the sun's heat a mystery. And science is based on the belief that the universe is not mysterious, though it is certainly complicated and strange. In the words of a very distinguished physicist,* nature is natural. So those who agree with him were delighted to find that the source of the sun's energy can be discovered in the laboratory.

A few years ago we used to read sensational stories about what would happen when atoms were split. The coalminers were to be put out of work by atomic power. A single bomb would liberate enough energy to destroy a whole city. And so on.

Unfortunately the prophets had forgotten to do a few little calculations. The sun turns out energy at sixty horse-power per square inch, which sounds very im-

* C. G. Darwin.

pressive. But if we make the calculation in a rather different way, we find that it is only producing one horse-power for every three thousand tons of its weight.

I am an optimist, and I hope that within a century it will be possible on earth to construct a motor using atomic energy as efficient as the sun. If so it will probably weigh a ton, and develop several mouse-power! It is true that it will not need refuelling for a good many thousand million years, but it will not earn a thousandth of a per cent interest per year on its cost.

That figure will perhaps be exceeded later on,* but the universe is pretty solidly constructed, and atoms are remarkably tough, so I think many generations will elapse before atomic power is of practical importance. But on the way to this perhaps unattainable goal, scientists will find many things of value. Already this research has given us artificial radio-active elements, which are now being tested out as substitutes for radium in the treatment of cancer.

There is however a quite different reason why our descendants will want precise information about the sun's inside. Our sun seems to be a typical middle-class star, neither very large nor very small. Such stars have an awkward habit of exploding. The explosion lets loose an immense amount of heat and light, so that a star which was only visible with a powerful telescope becomes one of the brightest in the sky, and may sometimes even be seen in broad daylight.

After the explosion the star settles down again within a few years as a so-called white dwarf, much smaller than its original size, but giving out about the same total

* Recent work on uranium suggests that this may be sooner than I thought.

amount of light and heat, and therefore a great deal more per square inch.

Astronomers do not yet know whether all stars go through this process once in their lives, and they do not know the premonitory symptoms of an explosion, though they have a fairly good theory of why it happens. But within a few hundred years the whole matter ought to be cleared up, and it should be possible to say whether the sun is likely to blow up in this way, and if so when. However, the date will probably not be certain within a few thousand years.

Very likely it will turn out that the sun is safe for another thousand million years. But let us suppose that the astronomers put the date only a few hundred thousand years ahead, what then? The explosion of the sun would certainly burn up every living thing on the earth's surface, blow away our atmosphere, and boil off the oceans. But it would only melt the rocks for a few feet down, and men a mile below the surface would be in no danger except from earthquakes.

So the government of a scientifically organized world community would see to it that at all times a reserve of the human race, and of useful animals and plants, with food, air and water for a century, was kept well underground, with adequate arrangements for coming up to the surface and restarting life there when the sun resumed normality. Probably a good deal of our present atmosphere and oceans would also be stored underground.

For the present we need not expect such sensational predictions. But we may get some help in interpreting and predicting the weather of our planet from a study of the sun's weather. On the outside of the sun we can see

spots and prominences. The spots are whirlpools of flame so enormous that the earth could be engulfed in one of them without being noticed except by a few careful astronomers on another planet. The prominences are great masses of hot gas shot out above the sun's surface. Both are due to forces in the sun's inside.

The spots have a considerable influence on our weather. At present they occur in maximum numbers every eleven years. The rainfall in some tropical districts keeps time with them. In the temperate and cool regions this is not so obvious, but the same period is found. The takings of the Hudson Bay Company show an eleven-year cycle because the fur-bearing animals such as arctic foxes, occur in greatest numbers every eleven years as a result of weather conditions.

We do not know the causes of this cycle. We do not know whether it may be expected to go on indefinitely, like the tides, or to die out like the waves after a storm. We do not know whether the same causes that give us our present little weather cycles may have caused warm periods and ice ages in the past.

We shall only be able to answer these questions when we have got a theory which will explain fully what we can see on the surfaces of the sun and the other stars. This theory is being rapidly built up as a result of the debates which are now going on. It will give us a new chemistry, a new physics, and a new meteorology. The interior of the sun is something of great practical importance, and knowledge of it is going to affect all our lives.

UNSOLVED PROBLEMS OF SCIENCE

IV. Can We Make Life?

How did life start? Two great inventions have given us some hints towards an answer, but left us still guessing. The first invention is the microscope, which showed that there were many plants and animals far simpler than any that can be seen with the naked eye.

The second invention is called zoning. William Smith, an engineer, who was in charge of the construction of several English canals round about the year 1800, saw that he got to progressively older rocks as he went westwards, each with its characteristic fossils.

As you go back the fossil animals become simpler. On the way from Caernarvon to London we should find the first skeletons of fish in Shropshire, of land animals in Staffordshire, while the bones of warm-blooded animals of the modern type would not be found before Hertfordshire.

The fossils were first used for dating the rocks, just as we can tell the age of a ruined house by the coins and pottery found in it. Later on Darwin and others made the same fossils tell the story of evolution of animals and plants.

But these two great inventions take us only half-way towards our answer. For there are living things too small to see with a microscope, and the fossil record is incomplete. Before the Cambrian rocks of Harlech were formed there were living things which have left a few fossils, but

not enough to tell any clear story. This is partly because most of the old rocks are buried and most of those which are now exposed have been baked and crushed. But it also seems as if the first animals were soft-bodied, without much in the way of shells or bones.

The fossil record is like the third volume of a Victorian novel. We know a lot about the recent adventures of our hero, Life, but we do not know where or when he was born. Many people are content to give up the quest, and to say that the origin of life is a mystery beyond the range of science. This may prove to be true. Some scientists think so. But others are not so modest. They say that if life once originated from dead matter it ought to be possible to repeat the conditions, and make life in the laboratory. If they fail, that will be a triumph for believers in tradition. It will show that some things are beyond human power. But they must be allowed another hundred years or so of attempts before they are adjudged as failures. Men had tried to fly for several centuries before the Wright brothers succeeded. And making life will be a harder task than flying, because the machinery of a living thing is on a scale too small to be seen even with a microscope.

Let us see how the problem is being attempted. Even the simplest living thing that we can see with the naked eye is fantastically complicated. To aim at building a worm or a moss-plant out of laboratory chemicals would be like trying to build the *Queen Mary* before one had made a rowing-boat. Even the bacteria which we can only see with a powerful microscope are far too large and complicated for anyone to try to make one with the faintest chance of success. It is true that model cells have been made which show some of the phenomena

of life, but they will not grow and reproduce themselves indefinitely.

The bacteria which cause water-borne diseases, such as typhoid fever and cholera, will not go through a porcelain filter. But other smaller agents of disease will do so; for example, those which cause smallpox and influenza. We cannot see most of these filter-passers even with the best microscopes, because they are smaller than the wave-lengths of light. We can, however, find out their size, at least roughly, by means of specially devised filters with very small holes. They include agents of disease, harmless living things, and parasites which kill disease bacteria, as these latter kill us.

The most reliable test of whether a thing is alive is whether it can reproduce its like indefinitely if given the proper food. Of course, some living things cannot do so; for example, double-flowered stocks or castrated animals. But until recently no one doubted that a thing that can reproduce itself is alive. A child is vaccinated, and the fluid from its arm can be used to vaccinate a score of others, and so on indefinitely. So, though we cannot see the agent, it is generally thought to be alive.

But in 1935 Dr. W. M. Stanley, of the Rockefeller Institute for Medical Research in New York, made a discovery which marks an epoch in science comparable with Pasteur's discovery of disease bacteria, or Schleiden and Schwann's that animals and plants are made up of cells. Stanley is working with the mosaic disease of tobacco plants, which causes yellow patches on their leaves. He claims to have got the agent of this disease in a pure state, and to have crystallized it.* It is a protein—that is to say, a member of a definite and common

* This has been fully confirmed. (See p. 121.)

class of chemical substances. But yet if a crystal of it is dissolved in water and injected into a plant it spreads through it, and hundreds of other plants may be infected. From them millions of times the original amount of crystals may be obtained.

Here, then, is a chemical substance which may be kept in a bottle and shows no signs of life. But given the right food it can reproduce itself. Clearly, the gap between chemistry and life has been very much narrowed. Critics can still make two objections. They can point out that these crystals have not been made artificially, and they can say that they are not really alive, but somehow persuade the tobacco-plant to copy them. However, a protein molecule is built up of only about 100,000 atoms, arranged in a definite pattern, so it should be possible to build up this one artificially within the next thirty years. And other filter-passers can reproduce when feeding on dead matter.

This discovery has immense possibilities for good and for evil. On the one hand, it may lead to a thorough understanding of filter-passers, so that influenza and common colds will be as easily controlled as typhoid fever. And it may be possible to make new diseases so deadly and so specific that they will wipe out a whole species of animals or plants without affecting others. The world would be a definitely better place without fleas, lice, and bed-bugs, and this is one of the possible ways in which they may be abolished. It is equally possible that man will turn the same weapons on himself. A new disease as deadly as smallpox and as infectious as influenza would be a weapon compared to which explosives and poison-gas would be as antiquated as bows and arrows. If a belligerent nation could immunize itself against it

before turning it on the enemy it might hope to win a war against enormous odds. It is worth noticing that the old gentlemen who framed the international convention which forbade the use of gas in war did not forbid such weapons. They forbade 'bacteriological warfare', but they had probably not heard that many of the worst diseases are caused by agents much smaller than bacteria. The present international law is as silly as would be a law forbidding the scale of rifles but allowing that of automatic pistols. However, as the present convention is violated with impunity, this does not very much matter. Somewhere about 1990 these new weapons should be available, and unless by that time the human race has done something serious to abolish war it will have to take the consequences.

It may be that artificial life of a simple character will be made in the laboratory long before we understand the process going on inside the cells of more complicated animals and plants. For here, too, as soon as we get out of range of the microscope we are working, quite literally, in the dark. We know a great many of the substances found in living cells, but we do not know much about how they are arranged. It is as if we had piles of most of the parts of which a watch is made, but no clear idea of how they are put together.

One of the real scandals of science is that we do not know how a muscle works. When I lift my hand various muscles contract. I know what fuel they are using, and can analyse the gas produced by its burning, which is carried by the blood of my lungs and breathed out. But I do not know just how the energy makes the fibres contract, as I know how the gas in my car pushes the piston. There is no mystery here. The will does not

come into the story. I have had the blood supply to my arm blocked till it was paralysed, and then watched another man stimulate my nerves with electric currents so that he could work my muscles when I could not. The problem is a problem of chemistry, not of psychology. And it is a practically important problem. When we burn fuel in an engine we use its heat to expand gas or vapour. But in muscles it is burned at a low temperature. We can imitate this process in the laboratory, but we cannot yet turn the energy into useful work. If we could, it might revolutionize industry. For a muscle has an efficiency of about 50 per cent., while few heat engines reach 25 per cent.

The way in which the machinery of a muscle is arranged is gradually being discovered by X-rays. These are vibrations like light, but of a much smaller wavelength, so that they can give us pictures of atoms. Unfortunately, we cannot bend X-rays as we can bend light with a lens to give us a picture. So we have to rely on indirect methods. However, the work goes on, and we ought to have fairly good artificial muscles within a generation. They will certainly be more efficient than our present engines, but a good deal bulkier. A one horse-power engine will not be as large as a horse, but it will at first be as large as a small sheep. And when properly designed, it will last a very long time, because none of its parts will get hot. As fuel becomes more expensive owing to the exhaustion of oil and coal, such engines will begin to pay, and it is probable that they will replace our stationary engines. But they will be too bulky to be useful for aeroplanes or vehicles.

Animals, and particularly plants, are very expert at making a variety of chemical substances, and arranging

them in patterns, such as wood, wool, and cotton. We are just beginning to copy them; for example, by making artificial dyes and artificial silk. But our chemical processes are carried out at high temperature, involving a great waste of energy. We know how animals and plants break down complicated substances; for example, how a man digests meat or a potato plant turns the starch of the tuber into sugar to be used in building new roots and shoots in the spring. This was discovered during the last thirty years. But we are only just beginning to find out how it builds up more complicated substances, and certainly cannot imitate this process. However, we know enough to say that the process is not mysterious but merely complicated. It looks as if the factories of the future would contain no heat engines, and that most processes would be carried out at normal temperatures. But these factories will not be mere imitations of living creatures. Invention is well ahead of life at many points. Life never produced the wheel. Nerves are most inefficient compared with telegraph wires. Nervous impulses only travel at speeds up to 100 miles an hour, while telegraph and telephone messages travel many thousands of miles per second.

The industry of the future will only copy life where it cannot improve on it. Unfortunately, progress along these lines is very slow because people in general are not interested in them. It is far easier to get £100,000 for a telescope than £1,000 for a number of rather dull-looking glass vessels needed for chemical analysis of living tissues. This is because one can write about the stars in simple language, but I defy anyone to do so about the ultra-microscopic world which lies between the cell and the atom. It is there that our ignorance is

most profound.* It is there that the outstanding problems of medicine will be solved. And it is there that discoveries will be made in the next century which will not only revolutionize medicine but industry, and (if we are stupid enough to let them) war also.

* See p. 120.

UNSOLVED PROBLEMS OF SCIENCE

V. What is Race?

THE problem of race is daily becoming more important for two reasons. Britain, France, Holland, and other European states still have empires whose inhabitants mostly belong to coloured races. The United States has the even more formidable problem of the coloured descendants of the negro slaves. Should we try to treat these people as equals, to be given full citizenship and equal rights with ourselves within the next century? Or should we recognize that they differ from us so greatly in inborn mental characters that no real equality is possible?

Nearer home we have trouble of a different kind. The present German government proclaims that Jews whose ancestors have lived in Germany for centuries are not Germans. They also say that millions of people living in Denmark, Poland, Czechoslovakia, Austria, and Switzerland belong to the German race, and ought to belong to the German state. Is this true? Should political frontiers be based, not on geography, language, religion, or economics, but on racial differences?

Before we can even try to answer these questions we must ask, 'What is race?' I open a German textbook on the subject, and read that a race is a group of men who are all alike in body and soul. This is obvious nonsense. Among people who certainly belong to the same race there are large differences both of body and soul. There are tall and short, dark and fair, good and bad, clever

and stupid, and some of these differences are obviously not due to upbringing.

Members of the same race are not exactly alike. They are not even as like as different members of the same animal breed, say White Wyandotte fowls or Sealyham terriers. That does not mean that race is a word without meaning. Unfortunately it means two different things.

On the one hand, if you take a thousand negroes and a thousand Europeans the palest negro is darker than the swarthiest European. There is no overlap between the two groups, and no doubt as to the race to which any chosen man belongs. Also we know that these differences are inherited, even if negroes live in cold countries and Europeans in hot countries.

On the other hand, if you take a thousand Swedes and a thousand Spaniards, or any other two groups within Europe except perhaps the Lapps, you find a very different state of affairs. On the average the Swedes will be much fairer and rather taller than the Spaniards. But the darkest Swede will certainly be darker than the fairest Spaniard, and the shortest Swede far shorter than the average Spaniard. The two groups will overlap. It will not be possible to say whether any particular man is a Swede or a Spaniard by looking at him or even by measuring him.

Some anthropologists tried to get round these awkward facts by a beautiful theory. It was supposed that long ago the population of Europe consisted of 'pure' races, whose members were all closely alike and which did not overlap, any more than white men overlap with negroes.

This was a lovely theory till it was tested. The chief original races in Western Europe were supposed to be a

Nordic race, tall, with long heads, fair hair, and blue eyes, an Alpine race, short, with round heads and brown hair, and a Mediterranean race of medium height, with long heads and dark hair and eyes.

The various races were supposed to have had their own psychological characters, but it was generally held that the Nordic race had a monopoly of certain virtues, and was therefore fitted to rule the others. Curiously enough, this is generally believed in Germany, although Herr Hitler is a typical Alpine!

Unfortunately one day it struck Dr. Morant, an anthropologist at University College, London, that if this theory were true, the populations of modern Europe ought to be much more variable than they were in the past. We cannot record the hair and eye colour of ancient men, but we can measure their skulls.

If we go to Northern India, where there has been a tremendous mixture of nearly white invaders from Persia and Afghanistan and yellow invaders from Tibet and Burma with black natives, we find every colour from pale yellow to dark brown. And we find a fair variation of skull-shape.

But if we measure skulls of ancient Britons, Anglo-Saxons, or other ancient races in Europe, we find that their skulls are just as variable as those of a modern population. The races of the past were no purer than those of to-day. There never was a pure Nordic race, and so an account of its virtues is not of much interest.

In the same way there is no German race to-day. The north Germans are fair-haired, blue-eyed, and long-headed, the south Germans dark-haired, round-headed, and often brown-eyed. Of course in both cases one can only speak of the majority, for there are plenty of excep-

tions. But there is no hereditary character common to all Germans and not found in other peoples.

On the contrary, if Europe were divided up on a basis of physical characters, Germany would certainly be split. The fair-haired north Germans would be united to Denmark and Sweden, the darker southerners to Austria and Switzerland. The present European frontiers may be bad, but frontiers based on racial differences would be far worse.

The truth is that if we are ever to understand the racial problems of Europe, we must solve a number of biological problems. How are differences of hair and eye colour, and of head shape, inherited? A first start has been made on this problem, but it is extremely complicated, and a great deal of nonsense has already been written about it. For example, some books on heredity contain the statement that two blue-eyed parents never have brown-eyed children. This is untrue, but has caused unjust suspicions in several cases.

When we have answered this question we must ask whether there is any real relation between physical and mental characters. It is said that blue-eyed men are more likely to be good sailors than brown-eyed. It may be true that a larger proportion join the navy and the mercantile marine. But this does not prove that the spirit of the Vikings goes with blue eyes. Naturally enough, they are commoner on the coasts than inland, because the Anglo-Saxon and Danish invaders who settled there had blue eyes. But no one has yet proved that within a single town such as Harwich or Grimsby a larger proportion of blue-eyed than of brown-eyed boys take to the sea.

It would be unscientific to say that there can be no connection between racial origins and mental character-

istics in a country like England. It would be equally unscientific to say that any such connection was proved. Even in the case of the Jews no one knows how far the virtues and vices which are commoner among them than the rest of us are due to tradition. Certainly the Quakers are as different from the general population as the Jews. For example, they produce a very large number of scientists. But no one has yet written of a Quaker race.

Even if we cannot clearly distinguish races within Europe, the distinction between European and most other races is clear enough. Two important questions must be asked. First, do some or all of these races show psychological characters which prevent them from absorbing our civilization? Second, what happens when they are crossed with Europeans, and is the result harmful?

We can at once answer that members of many of the other races can reach our level. Japan is more civilized than some European states. China is painfully but fairly quickly adopting our ways of life. In New Zealand a Maori acted as Prime Minister for some time, without anything beyond the usual grumbling from the million or so whites whom he governed.

It is not so certain that the black races of Africa can do equally well, and quite certain that they have not yet proved their capacity. The Australian blacks are hunters. They huddle round fires in cold weather. But they had never thought of making clothes from the skins of the animals they killed. I find it hard to believe that their descendants will produce a Watt or Edison.

Yet every effort to show scientifically that blacks are by nature mentally inferior to whites has failed. American negroes do not do so well in intelligence tests as

whites in the same state. But negroes in a progressive state such as Ohio do better than whites in a backward state such as Arkansas. So the differences between blacks and whites in the same state may depend entirely on differences of upbringing.

Some day a scientifically minded philanthropist will bring up a thousand white and a thousand black children side by side in the same orphanage with exactly equal treatment and compare the results. Until this sort of thing has been done on a large scale we must realize that both the advocates of racial equality and their opponents are speaking without scientific backing. The problem is still open, and will only be solved by scientifically conducted experiments.

Some race mixtures are quite successful. The railways of India are largely worked by men of mixed Anglo-Indian blood. On the other hand, it is said that the Cape coloured people of South Africa, who are also hybrids, are less healthy than either whites or blacks. But we have no really scientific evidence on this question, which is vital for the future of the British Empire. It could probably be settled in ten years if the men and money needed for the purpose were available.

Apart from such superficial characters as colour and shape of the face and hair there is one very important respect in which races differ, namely, in immunity to disease. Englishmen cannot colonize West Africa because they die of yellow fever, while negroes rarely do so. Negroes in England very often die of consumption.

But can Englishmen live and breed satisfactorily in very hot countries where there are no very serious diseases, such as the Northern Territory of Australia, or in sunny but not very hot lands such as Rhodesia?

My own opinion, which however is only a guess, is that most Englishmen could live and work in very great heat, provided they had the proper houses, clothing, and diet. But this is a matter for scientific investigation. The problems to be solved are not particularly difficult. Here are a few of them.

Are there big differences between the capacities of different races for sweating, which is nature's way of keeping cool? Do Europeans who can sweat well stand life in the tropics better than those who cannot? Can people be taught to sweat better, and if so how?

If Europeans in the tropics spend sixteen hours a day in a refrigerated house, can they work better for eight hours a day in great heat than men who are hot for twenty-four hours a day? My experience of hot coal-mines suggests that the answer is 'yes'. If so, houses in the tropics should be provided with large refrigerators as universally as English houses are provided with fire-places or hot-water pipes.

These and many other questions could only be answered by experiments on hundreds of men. They might be tried on a British battalion in India or Malaya. If they related to machines they would have been made long ago. But we find it much harder to think scientifically about ourselves than about machines.

As an example of peculiarly unscientific thinking on the subject I commend the remarks of Mr. Beverley Nichols in a book called *The Fool Hath Said*, which is supposed to be about religion. He calls upon the Australians to hand over their Northern Territory to the Japanese, because the Japanese can live there healthily and men of English stock cannot. The Japanese have lived for thousands of years in a temperate climate, and

there is not a particle of evidence that they are any better adapted to tropical life than the Australians.

This sort of propaganda is just as unscientific as Herr Hitler's theories about race. And if it continues to be backed by clergymen in responsible positions it may be taken seriously, in which case it will do incalculable harm.

There is one still harder question which will have to be answered, though it will not be answered in our time. How do races originate, and how do they change, apart from a mixture with other races? One of the tenets of the German racial theorists is that racial characters are fixed, that the Germans to-day have the same essential characters as their ancestors who lived in forests two thousand years ago, and the Jews do not differ from the men who followed Moses into the wilderness.

Yet almost the only point on which evolutionists agree completely with fundamentalists who believe in every word of the book of Genesis is that all human races are descended from the same ancestors, and have since come to differ. The followers of Darwin think that negroes became black because the darker skinned among their ancestors were less affected by the sun than the fairer members and thus left more children.

We must therefore ask whether the white Australians, who certainly get more sunburnt than the English, will gradually darken, until even babies are born brown. The answer is probably that such a change would take thousands of years, and that within a few hundred we shall know enough to control it if we want to. But we cannot be sure. No observations are being made which would enable us to answer the question with certainty. And if skin colour is really bound up with mental characteristics it is a pretty important question.

The most disturbing fact about these problems of race is not that they are unsolved, but that no one is trying to solve them. We go about believing them to be solved, choosing a solution which fits our political views. Yet these questions can be solved scientifically, and the future of the British Empire depends on the correct solution being found.

UNSOLVED PROBLEMS OF SCIENCE

VI. Secrets of Health

My friends continually ask me questions about their health. Ought I to wear cotton next to the skin? Ought I to eat so much meat? Should I take more exercise? Will my children inherit my asthma? Is it safe to sunbathe till one gets as brown as Miss Robinson? Ought I to have my dead teeth out?

My answer is almost always, 'I don't know.' And sometimes I add, 'Nobody else does either.' I might go further and say that I have never yet met a healthy person who worried very much about his health, or a really good person who worried much about his own soul.

My friends find this very trying and go on to someone else who answers their questions with complete assurance. Thirty years ago the answer to such questions had to contain the mystic word 'germs' or bacteria. Now, to be up to date, one should mention vitamins, glands, or complexes. Thirty years hence perhaps the keywords will be enzymes, genes, and viruses.

This does not mean that germs are a discarded fad. Far from it. After such diseases as typhoid fever and cholera had been wiped out in England by abolishing their germs, people naturally thought that killing germs was the only secret of health. Nor are vitamins a fad. A proper supply of vitamins to all children is immensely desirable, except for dentists, who will have a lot less to do when people have been properly fed for a generation.

Faddism only begins when we ascribe every obscure

disease to our pet cure, whether physical or psychological. There is no single prescription for health. The human body may go wrong in thousands of ways. But it is possible to see where some of the next advances in health will come.

Pneumonia is one of the commonest causes of death. The lungs are generally found to have been invaded by a germ called the *Pneumococcus*, of which there are a number of different races. At first it was hoped that by abolishing the *Pneumococcus* we might wipe out pneumonia. But it was soon found that quite healthy people might carry the *Pneumococcus* in their throats without getting pneumonia. The same holds good of several other diseases.

We do not know all the causes which will permit a microbe that is normally harmless to attack our organs. But we do know one. That is the assistance of a virus, an infective agent too small to see with the most powerful microscope. Some viruses, such as those of measles and smallpox, can kill you without assistance. Others are not very dangerous alone.

The virus causing influenza is unpleasant but rarely fatal by itself. But sometimes it begins to co-operate with visible microbes which are fairly harmless in themselves. This is what happened in the great pestilence of 1918, which killed more people than the war and the Russian revolution together.

Between the armed forces and the munition makers we have the best part of a million people preparing our defences in the next war. About three men are studying gangster microbes in England.

A good many more than this are studying vitamins. As the result of their work we believe that we know pretty

well what is the minimum diet needed for health. If I were a millionaire I should spend £250,000 or so on testing the theories of the biochemists on men, by putting ten thousand people in one of the depressed areas for a year on the cheapest diet considered adequate by scientists, and testing its effect on their health by comparison with ten thousand people on an ordinary diet. The result would either condemn a number of distinguished scientists as faddists, or compel our government to realize that a proper diet is as essential to public health as a proper water supply.*

Until this is done, we must, I think, accept the results of smaller experiments, and say that the unsolved problem here is not a scientific one, but the economic and political one of how to see that people are properly fed.

But at this point we meet with rather formidable opposition. There are many people who say that with the best hygiene and diet in the world a great number of people are condemned from birth to ill-health. As a result of bad heredity they are doomed either to physical or mental illness. Unless we can root out these degenerate stocks we are only tampering with the problem of health.

They go on to tell us that we can deal with this problem by sterilizing the unfit. I am not going to discuss the rights and wrongs of sterilization. That is an ethical, not a scientific problem. The scientific problem is as follows. Only about one blind person in ten at most had a blind mother or father. The same is true of mental defectives. So sterilization would only wipe out about one-tenth of

* I was an optimist. Lady Williams' experiment on maternal mortality in South Wales has had no effect on public policy.

the blindness and mental defect in England in the first generation, and much less in later generations.

Yet a great deal of blindness and mental defect, as well as of other maladies such as deafness and skin disease, is due to a subtler kind of heredity. I can show you two quite healthy mice and tell you that if I mate these two together, one-quarter of their children will be wretched deformed creatures with no teeth, destined to die within a month or two of their birth.

A character of this sort is called a recessive character. It may be carried by an apparently normal person, and will only show up if two such carriers happen to have children. About one person in a hundred is a carrier of a particular kind of idiocy. It is nearly a hundred to one against him marrying a woman carrying the same abnormality. But if he does so, one in four of their children will be an idiot.

Other normal people carry latent deaf-mutism, albinism, and other defects. They are more likely to produce a defective child if they marry relatives than if they marry someone who is not related. But even if we forbade cousin marriage we could only wipe out a fraction of such maladies.

One of the great unsolved problems of science is how to detect these latent characters below the surface. There is no question of sterilizing the carriers, but only of preventing two carriers of the same defect from marrying. The problem is not insoluble. A mouse which is a carrier of albinism may be as black as jet, but if you give him a temporary bald patch with X-rays (an entirely painless procedure which is used in treating children with ringworm) the new hair which grows there is at first grey.

There are other ways by which these latent defects could be detected. In fact I am working on one of them at the moment. And very gradually it should be possible to find out what is below the surface in a man or a woman, though it will probably be some centuries before the task is complete.

Even to-day everyone ought to be medically examined before marriage. For quite apart from hereditary diseases it is hardly fair to marry and beget children if one is liable to fall dead with heart disease at any moment. But in future a couple, before they become engaged, will see not only that they have no heritable defects, but that they have no latent defects in common.

It is useless to worry about such possibilities at present. The odds are many hundred to one against two normal parents producing an idiot child. But the possibility is there. Marriage will always be a gamble, but science will make it less of one.

There is another way in which the study of heredity will be an aid to health. It will force us to recognize the huge individual differences in healthy people. Mr. Smith enjoys radiant health. He puts it down to drinking a quart of milk a day, and he may very well be right. But he annoys his friend, Mr. Brown, by preaching the gospel of milk, for Mr. Brown finds that it makes him sick. It is a great biological truth that one man's meat is another man's poison.

My friend, Mr. Jones, finds that he cannot keep healthy without taking violent exercise twice a week, and is horrified when I tell him that I take none except during the holidays. As, however, I can walk up Snowdon or swim a mile without training, I do not think that I need regular exercise. But I don't call Mr. Jones a faddist.

The problem of the individual constitution is one of the great unsolved scientific problems. There is a certain minimum of diet and hygiene which ought to be universal. It is perfectly true that some people can drink water full of cholera bacilli without getting cholera. A German physiologist called Pettenkoffer did so. But the rest of us rightly insist that our water should be free from such germs.

Yet we do not insist that the sale of lobsters should be prohibited because they give some people nettlerash. It is everyone's business to find out what food agrees with them, whether they need regular exercise, how much clothing they should wear, and so on. It is also their business to realize that what is good for them at thirty years of age may be dangerous at fifty.

Unfortunately scientists have hardly begun to tackle this problem. But they are making a start. Some races of mice are prone to particular diseases, such as cancer and typhoid fever, others are not, and the heredity of these conditions is being studied.

It is all very well to tell people to study their own bodies. We must not, however, exaggerate. If everyone was continually worrying about his or her health we would become a nation of neurotic invalids. If no one paid any attention to it people would go on working till they dropped dead, when a week in bed would have saved their lives.

This brings us up against another unsolved problem. How much disease could be prevented by mental hygiene, by right thinking and feeling? The Christian scientists answer 'all diseases'. But yet they die like the rest of us, from very similar causes. Some psychoanalysts say very much the same thing. How are we to

decide this question? There are no statistics, and experiments on men would be very difficult.

For the proper mental attitude implies a contempt for those little aches and pains which many of us suffer in youth and most in middle age. But along with this goes a vigilance against the first signs of cancer and heart disease. It is here that the doctors score over the rest of the population. They treat these diseases early, and have a very low death-rate from them. But they die on a large scale of infections caught from their patients. Their death-rate from influenza is far above that of the population in general.

A few experiments have been made on animals which seem to show that some diseases in rabbits can be cured by what would be called psychological methods if they were applied to men. But we shall only get at scientific certainty by experiments on human beings. They are likely to show that faith, in the quantity which most of us possess, can be an important agent in the cure of some diseases but not of others. In many forms of paralysis about half the symptoms are due to physical changes in the nervous system, and the other half to the patients' lack of faith. If you can restore the faith either by religious or secular means, you can relieve the symptoms to a great extent. In hysterical paralysis psychological methods may bring about a complete cure. But no amount of faith has ever cured paralysis due to a cut nerve.

In future, medical scientists will investigate the extent of the psychological elements in different diseases, and at the same time tackle the problem of mental hygiene, that is to say the proper attitude of the mind to the body. We shall not help them by answering these questions in

accordance with our own particular brands of religion or irreligion, rather than in accordance with facts.

I have written of some of the problems which are now engaging medical scientists. But the greatest problems are probably not merely unsolved but unasked. Nature will generally answer our questions if we ask them in the right language. The problem of diet became a scientific one when Hopkins asked, 'What kinds of chemical substances which the human body needs is it unable to make?' These are the essential substances in a diet, and include the vitamins.

If the human race can produce a few men in each generation who ask the right questions, and are given the means of answering them, the fight against disease will go on as successfully as it did during the nineteenth century. This will only be possible if ordinary men and women realize that the problem of disease is enormously complicated, that there are no short cuts to universal well-being, and that although the science of man is vastly more complicated than that of machines, it is the only key to the secrets of health.

WHAT IS LIFE?

ONE of our greatest difficulties in answering a question like this arises from language. We use words, and are inclined to think that a thing must correspond to every substantive. Now some substantives stand for things; for example, bricks, water, and coal gas are things. Others are more doubtful. For example, a wave moves over the sea. We say that it is the same wave now as five minutes ago, but the particles of water in it are quite different. A tune has even less claim to be called a thing. It may be being played in several places at once, or nowhere. And some substantives like greenness or cleverness stand for qualities which no one except a few philosophers supposes to have any existence of their own.

Where does life belong in a classification of this kind? When a man dies we say that he has lost his life, or that life has gone out of him. Is that just a metaphor? Is death the loss of something, or merely a change of state, as when a snowman melts, or a pattern is disarranged? The first people of whose ideas on this subject we know anything thought that life was the same as breath. But we know that the breath consists of gas, which can be made into a solid or liquid, and also that many living things do not breathe. Life is certainly not a kind of matter. When a man or an animal dies he does not lose or gain in weight. Nor is there any measurable loss of energy. The heat gradually leaves the body, but it is doing so throughout life. A dead body cools because

no more heat is being generated inside it, not because anything measurable leaves it at the moment of death.

Our ancestors thought that anything which moved itself was alive. And before the days of machinery that was quite a good definition. But a machine such as a motor-car or a steamship moves itself, and as soon as machines which moved themselves had been made, people asked, 'Is man a machine?' The philosopher Descartes thought that both men and animals were machines, but that the human machine was partly controlled by the soul acting on a certain part of the brain, while animals had no souls. And some scientists think that life is just a very complicated mechanism.

Though we shall not accept this theory, there is a good deal of truth in it, and it is worth examining. A great many of the differences between animals and machines are due to the mere fact that animals are so much more complicated. The higher animals are built up of cells which, as we shall see later, have a life of their own. Now in a dog's brain there are something like fifty million nerve-cells, each connected up with many others, and in touch with the outside world by nerves leading from the sense organs such as the eye, and to the muscles. The nerve from a dog's eye consists of at least a hundred thousand fibres, each of which can transmit a message independently of every other, like a number of telephone wires running side by side. Further, each cell consists of many thousands of parts each of which is different from every other. Such a complicated machine may be expected to have properties not found in any machines we know. Our best machines regulate themselves to a great extent. Even ordinary steam engines

have governors. Perhaps an animal is only a very perfect self-regulating machine.

What is more, we can find out a great deal about how this living machine works. Many of the bones are levers. For example, when we shut our mouth we can feel the muscle under the cheek contracting and pulling up the lower jawbone which is hinged to the skull just in front of the ear. The heart pumps the blood round, and an artificial heart can take its place and keep an animal alive after it has stopped. The eye is not unlike a photographic camera in construction. The lens focusses light as does that of a camera. Each has an iris, or stop, which is opened up in dim light and contracted in bright light. The chemical processes which occur when light strikes the sensitive film at the back are not so very unlike in the eye and the camera.

And this resemblance is not superficial. It used to be thought that the events inside a cell were of a special kind not met with in dead matter. For some time chemists could not put together the complicated organic molecules of which living matter is built up. The first one was, however, made just over 100 years ago, and in the intervening century over 100,000 kinds of organic molecule have been made. So with the details of how the chemical processes are carried out. These have been studied, and very curious they are. But we can now imitate them in the laboratory.

Why, then, should we not 'go the whole hog', and say that animals and plants are just machines, adding, if we like, a soul in the case of man, and perhaps some of the higher animals? First, let us ask what we mean by a machine. I think we mean a system capable of performing some function (say making a noise or cutting wood)

which is made up of replaceable parts, and which can be fully understood when we understand about these parts. For example, if any part of a motor-car is broken, a new one can be got to take its place; and an engineer who knew enough about the parts could tell you a good deal about the car's behaviour. The opposite to a machine is an individual, something which from its very nature cannot be taken to pieces and put together again. Most plants are much more of machines and less of individuals than men or dogs. They can be cut in two and each part will live. Parts of different plants can be grafted together, and so on. But the parts of a man or a higher animal change their nature very quickly when taken asunder. Each part depends on the other parts to keep it alive. So an animal is in some ways a machine and in some ways an individual, and the science of biology consists largely in finding out how much of a machine, and how much of an individual. We can give a man false teeth, or transfuse a quart of blood from one man into another. But we cannot give him a glass eye with which he can see, or graft a leg from Mr. Smith to Mr. Jones.

Again, if animals and plants are machines, they are self-regulating, self-repairing, and self-perpetuating machines. A good example of the self-regulation is that of the human temperature, which is so steady that a small rise or fall is a danger signal. If we get too hot the blood flow through our skin is increased, so that it loses more heat, like the radiator of a car. If this is not enough we begin to sweat. We also take off clothes, go into cool places, and so on. The most obvious examples of self-repair are the perpetual renewal of the skin, and the healing of wounds. And the most remarkable process of all is reproduction. The science of physiology is

largely the account of how the minutest details of our organization, for example, the amounts of dozens of different substances in the blood, are exactly regulated. Now in a self-regulating machine some details, such as steam pressure, or speed of revolution, are regulated, but most of the parts are solid, and have a form and size fixed once for all. This is not so in a living being. Even solid parts, such as bones, are in a continual state of flux. In a full-grown man new materials are constantly being laid down in them, and as constantly removed. The steadiness of form in an animal is more like that of a flame or a waterfall than that of a house or a statue. As we analyse life it seems to resolve itself into self-regulation with no permanent structures to act as regulators. We have got a long way from the idea of a machine.

The machine theory also breaks down when we consider our minds. The mind has a unity of its own. Somehow the most diverse elements, sensations, emotions, thought and will, are held together. And yet in spite of this unity the mind depends completely on the body. Cut off the blood supply from parts of the brain, and the most intelligent man becomes a hopeless idiot. An attack of lethargic encephalitis often turns a previously good child into a little criminal. Serious damage to the frontal lobes may paralyse initiative. An injury to other parts of the brain may wipe out special faculties, such as memory for places or words. The mind depends on the brain, but it has a unity of a quite different kind to anything found in a machine.

Life, then, seems to be a synthesis of two opposites, mechanism and individuality. A man is a machine, and at the same time an individual. There is nothing really

surprising in this. We find the same union of opposites everywhere. Wood is both hard and soft. If it were not hard we could not use it for furniture. If it were not soft we could not cut it. We can ask of any living thing how much is it a machine, and how much an individual? And the answers are very interesting. For we find that both in the life of the individual and in the evolution of races, there is generally, though not always, a progress from mechanism to individuality.

A plant is not much of an individual. You can cut a geranium or a potato in two, and both parts will grow. You can graft a rose on to a briar, or even a tomato on to a deadly nightshade. The lower animals are the same. You can graft two sea anemones together, or cut a flat-worm into several bits, all of which will live. You cannot do this with the higher animals when they are fully grown. But you can when they are very young. Cut a frog in two and both halves die. But cut its egg in two at a certain stage, and you will get two rather small tadpoles. Even a human embryo at a very early stage may divide in two and give two so-called 'identical' twins.

So we can say that life is something between mechanism and individuality, but seems to strive towards greater individuality or oneness.

Even within a single living creature, life exists at several different levels. If you kill a rabbit and take its heart out, and then keep the heart warm and supply it with blood or some other suitable fluid, it will go on beating for many hours. A tortoise's heart will stay alive for months. This prompts us to ask the question, 'What is the smallest part of a living creature which still has life of its own?' If life is essentially organization, there

must be an answer to this question. If a man, animal, or plant were a complete individual, the separate parts could not have a life of their own.

Microscopical observation shows that both animals and plants are built up of cells, each surrounded by a membrane and composed of a kind of jelly, with a tougher body, the nucleus, in the middle. The size varies greatly, but an average human cell is about a thousandth of an inch across.

A single cell from a man or animal can live and multiply if given proper food. But if a cell is divided up, the parts will not live for any length of time. The technique of growing cells in tissue culture is one of the most remarkable of biological inventions. Cells from an embryo chick have been grown in a mixture of blood serum and embryo juice for over twenty years, or far longer than the chicken would have lived. They divide very rapidly, and some of them must be transplanted into fresh culture medium every few days. But they grow in a more or less disorderly way, and never organize themselves into anything like a chicken.

Life, then, in the higher animals and plants is organized at two levels. Each cell has a life of its own, and somehow or other all the cells co-operate in the life of the whole body. There are, of course, also simple animals and plants, mostly microscopic, which consist of single cells. But once in each life cycle, even of a higher animal or plant, life drops down, so to say, to the cellular level. In sexual reproduction the female forms eggs, which may be quite large, as with birds, or barely visible, as in the human species. The male forms spermatozoa or pollen grains, which are almost always microscopic. Eggs, spermatozoa, and pollen grains are all

single cells. From the fusion of an egg with a sperm or a pollen grain a new cell arises which divides into many more to form an animal or plant.

Now let us look at life from the chemist's point of view. All living things move. The motion may be quick, like the flight of a bird, or slow, like the growth of a plant, but it needs energy. They also grow, so they need nourishment. The atoms in living things are built up into large and complicated molecules. Some of these are common to a great variety, perhaps all, living creatures. All living things seem to contain a sugar called glucose, which was first obtained from grapes, but is also present in human blood. But every kind of living thing so far examined contains some substances which are found in it alone, and in no other sort of living creature. Doctors use this property to identify bacteria which are so small that even with a microscope they cannot be distinguished by their shapes. ■

The process of building up the living substance from simpler materials is called anabolism. There are two very different kinds of anabolism. Green plants, and some plants of other colours, such as the brown and red seaweeds, can build themselves up from simple inorganic substances with the aid of sunlight. Thus grass absorbs water and nitrates from the soil with its roots, and carbon dioxide from the air with its leaves, and uses the energy of the sunlight to turn them into sugar and other materials of life. Animals, and some plants, such as fungi and moulds, do not use sunlight, but break down the products of plant anabolism by a process called digestion, and then build them up again into the proper patterns for their own use. Even carnivorous animals live on green plants at second or third hand.

Thus the cat eats birds which have eaten seeds, the clothes-moth eats the cat's fur, and so on.

There are also two different kinds of catabolism. Most animals and plants get their energy from oxidizing foodstuffs, just as a steam engine gets its energy from oxidizing coal. But a few get it without taking any oxygen from the air, by merely re-arranging the atoms in their foodstuffs, as for example an electric battery develops energy without using oxygen. The oxygen-using animals and plants are called aerobes, those which do not use oxygen anaerobes. These latter include most of the bacteria responsible for bad smells, which are all due to volatile substances that might have been oxidized further; and many of those responsible for disease. Some organisms can live either aerobically or anaerobically. Thus yeast will oxidize sugar if it gets enough oxygen, but in the absence of oxygen, it turns sugar into alcohol and carbon dioxide.

From the chemical point of view, then, each sort of living substance is a particular pattern of chemical compounds, and each sort of life is a particular pattern of chemical change. The pattern of chemical change is very similar in related organisms like a man and a dog, not so similar in a man and a mushroom. Nevertheless, the patterns and their details are astonishingly alike all through the realm of life. I have discovered a particular chemical change going on in a rat, and next year found practically the same one in a bacillus, though of course forming part of a rather different pattern.

The simplest pattern of chemical change familiar to us is a flame. A candle flame keeps a fairly steady shape and size. Different changes are occurring in the different parts of it. Its matter is always changing. It can give

rise to other flames, and so on. Considered as a set of chemical reactions, a man is as much more complicated than a flame as a grand opera is more complicated than a blast on a whistle. Nevertheless, the analogy is real. In particular a flame is like an animal in that you cannot stop it, examine the parts, and start it again, like a machine. Change is part of its very being. Even apparently unchanging living things like seeds are really undergoing slow change, and using oxygen. That is why seeds cannot be kept indefinitely. In spite of stories to the contrary, the wheat in Egyptian tombs has long used up its reserves of starch, and starved to death.

Besides chemical changes, there are electrical changes taking place in all living tissue, and especially in the nerves; and by analogy with telegraph wires, some people have thought that the impulses or messages which travel along nerves were merely electrical waves like those in a metal wire. This is not the case. What travels along the nerve is a chemical change like that which runs along a lighted fuse. The electrical change is secondary to it.

If we pursue the chemical description too far we are apt to forget the fundamental fact that life is a self-regulating pattern of chemical changes, just as living things are self-regulating machines. For example, I move my arm, that is to say, I start off a very complex set of chemical changes in its muscles. They begin to use up oxygen. If extra oxygen were not supplied to meet this need the chemical changes would become abnormal, as they soon do if the blood supply to a limb is stopped. To prevent this the blood supply to my arm is increased. My heart beat and breathing are very slightly speeded up. Besides oxygen the muscle takes sugar out

of the blood. The level of blood-sugar is made up to normal from a special store in the liver. All this is regulated by the brain, though not consciously. In plants and simple animals the co-ordination is far less delicate, but it is always there.

Life is adaptive. We might almost say that it is adaptation. A plant grows so as to get light for its leaves and water for its roots. An animal seeks food or a mate. And every action of a part involves the co-operation of the other parts. The stem of the plant must grow strong enough to support the leaves. The muscles of the animal must be supplied with oxygen from the lungs or gills, sugar from the liver, and so on. All the main organs have functions. What is more, the individual chemical reactions have functions. If we poison a mouse with carbon monoxide, as when it is given coal gas to breathe, we kill it because we interfere with one particular chemical reaction, namely, the combination of oxygen with haemoglobin, the red pigment of the blood. We can also kill it by starvation if we break its front teeth and give it hard food. But just as we can keep it alive without teeth by giving it soft food, we can keep it alive in presence of carbon monoxide by giving it compressed oxygen. In this case the particular reaction which is stopped by carbon monoxide is no longer essential, because the blood can take up all the necessary oxygen in simple solution.

Some people think that we should not speak of the function of the heart, but the purpose of the heart. I believe that this would be misleading. Life is very efficient, but it is extraordinarily blind in the sense of being unable to adapt itself to novel circumstances, until, in the higher animals and man, it is illuminated

by mind. It probably is as big a mistake to regard life as purposive as to think of it as merely mechanical. The heart is a very efficient pump, and well regulated under normal circumstances. But it will go on pumping blindly if taken out of the body and supplied with warm water containing suitable salts and a little oxygen. Most animals, even of a very simple kind, can learn by experience, and seem to have some rudiments of mind. Plants cannot do so. The rose must be pruned every year. It does not learn to make flowers instead of wood. And many parts of the higher animals, for example, the beards of men who shave daily, are just as obstinate as the rose.

It is time that we looked at some of the imperfections of life. For life is never perfectly adapted to its environment. Some organs have no function whatever. For example, the dandelion produces pollen. In most plants the pollen is essential for the fertilization of ovules which turn into seeds. No doubt this was so in the ancestors of the dandelion. But the dandelion has given up sexual reproduction, and its pollen is absolutely wasted. Man has plenty of useless organs. The toenails are quite useless, at least to civilized men, and occasionally troublesome. Among internal organs the vermiform appendix is equally useless and more dangerous. But both these organs, like the pollen of the dandelion, were useful to ancestral forms. Every animal and plant probably has useless organs of this kind, which have been of use in the past. But other organs are not only useless, but so far as we can see, have never been useful in the past. Such are the lobe of the ear in man, and many fleshy outgrowths of birds, such as the cock's comb. Occasionally a use may be found for such a structure, and then it will develop further. And just as there are useless parts

of the body, there are useless chemical reactions within it. Further, many adaptations are incomplete. The different parts of the eye are so badly adapted that most men need spectacles at one time or another. Finally, no adaptations last for ever. All men, animals, and plants die. Yet this imperfection, while it is an evil from the point of view of the individual, is absolutely essential to life as a whole. Without imperfection there would be no evolution, as Darwin was the first to see.

There is a sense in which all life is one. Although life is manifested in countless millions of individuals (a single pound of soil may contain a million million bacteria) and though these individuals devour one another without mercy, it is not meaningless to speak of the unity of life. Thanks to the labours of palaeontologists who study fossils, and comparative anatomists who compare different forms, we can trace back the ancestry of the various kinds of plant and animal alive to-day. At the time when the chalk was laid down lived the common ancestor of men, monkeys, carnivores such as the dog, ungulates like the cow, and rodents like the mouse. In the swamps where our coal measures were formed, mammals like those mentioned above, birds, and reptiles had a common ancestor. The ancestors of all land vertebrates were fish who left the water while the Old Red Sandstone of Devon was being laid down.

The fossil record does not tell us of the common ancestors of vertebrates (such as the animals so far mentioned), insects, molluscs, and sea urchins. But their early development and the structure of their cells is so similar that almost all biologists believe in their relationship. Finally, it is believed that even animals and plants were descended from common ancestors. When we go

below the superficial characters the resemblances are overwhelming. Thus the laws of heredity discovered by Mendel in peas are found to hold without any modification for most human characters. The chemical reactions which take place when yeast makes alcohol from sugar gave the clue to those which provide the energy when a human muscle contracts.

However life originated in the remote past, more than a thousand million years ago, nowadays one living creature is always derived from another, or, in the case of sexual reproduction, from two others. And there are good reasons to think that all or almost all living things were derived from a single original. How, then, have they come to differ so greatly? If we study variation within a species, such as the hen or the snapdragon, we find that all sorts of deviations from the original type are inherited. Most of them are disadvantageous. But what is a disadvantage in one environment may be an advantage in another. For example, there are breeds of fowls with curly feathers, which die of cold in an English winter unless carefully protected, but live happily in the tropics. A white fowl would be conspicuous to its enemies in a wood, but inconspicuous against snow. However, the vast majority of variations are harmful in any environment. New variations are constantly arising by a process called mutation, and being combined with others by sexual reproduction. Thus by suitable crossing we can combine the crest of the Houdan fowl with the white plumage of the Wyandotte or the small size of the bantam. Sometimes a combination of variations which are harmful one at a time may be useful. Thus in butterflies the instinct of the female to lay eggs on a certain plant and the ability of the caterpillars to eat

it may be independently inherited, so that a cross between two races adapted to different plants come to grief. Laying instinct and digestive capacity must vary together.

Evolution may happen in several ways. A single favourable variation may spread through a species. A favourable combination of variations may be isolated in a particular area. Or a change in climate, food, or enemies may make a previously useless variation useful. A special type of variation, which is not uncommon in plants, makes the new race infertile with the ancestral form, and thus a new species arises.

But three conditions are necessary for evolution. A race must not be perfectly adapted to its environment, but must vary round the most perfectly adapted type. Individuals must die, to make room for fresh experiments of nature. And there must be an overproduction of individuals, so that the least fit are weeded out by natural selection. All these conditions are evil from the point of view of the individual, good from that of the evolving species.

But just as most individuals are failures in the evolutionary struggle, and leave no descendants, so are most species. Evolution generally ends in highly successful species with no future. The horse is too specialized to evolve into anything else. He has lost all but one of his toes and many of his teeth. He could never evolve into a climber, a swimmer, or a flier. The great steps in evolution have generally been made by relatively unspecialized animals.

As the result of evolution every animal and plant is a piece of embodied history, like the British constitution. It contains many vestiges of the past which have out-

lived their use, and a few untried variations, which may be, but probably will not be, the basis of further evolutionary changes. It is at once an anachronism and an experiment.

We see then that life is an extraordinary bundle of contradictions. It is something between mechanism and individuality, between chance and purpose, between happy but stagnant perfection and struggling but evolving imperfection. It is a process of continual change, yet embodied in very characteristic forms. It is a constant struggle against death, yet without death it could not progress.

The philosopher tries to define it, but no definition will cover its infinite and self-contradictory variety. The biologist studies it, well aware that he can never hope to fathom its full complexity. But every step forward in our knowledge of it brings it more under our control. Biology has already revolutionized agriculture and medicine. As man learns about human biology he will gradually come to apply reason in place of emotion and tradition in regulating his own life.

WHAT IS DEATH?

WE find no difficulty in speaking frankly to children about some very surprising facts, such as broadcasting and the roundness of the earth. We do not find it so easy to tell them about human reproduction and human death. This means that we ourselves have psychological resistances which prevent us from thinking clearly about such matters. That is why many readers will prefer to dismiss this article as shallow materialism, and a few as flabby idealism, rather than point out in detail what mistakes I have made.

Our ancestors identified life with breathing. 'Spirit' is only a Latin word for breath. We are now apt to identify it with the heart-beat, and every time that a man or woman whose heart has stopped for a few minutes recovers again, someone writes that the dead have been restored to life. These views are far more mechanistic than any which I hold. The heart is only a pump for blood, and the lungs a means of exposing it to air. We can already keep the rest of an animal alive for some hours with an artificial heart and lungs, and it is only a question of time before this is done with a man. One of the main difficulties is to prevent the blood from clotting in the artificial heart.

The facts about life are much more complicated. The opposite to a machine, which is built up of replaceable parts, is an individual, which cannot be taken to bits and put together again. Now man is a compromise between the two. We can do a certain amount of re-

placement with spare parts, as when we transfuse a quart of one man's blood into another. But man is only to some extent a machine, so we cannot do very much replacement of this kind. And when we say that a man is dead, we mean that his individuality has ceased rather than that his machinery has stopped working, even though the two events generally go together.

Let me explain. When you are dead I can take some of your white blood corpuscles and grow them in a suitable fluid, certainly for weeks, perhaps for many years. If I knew enough I could do the same with many of your other tissues. This is already possible with the cells of embryo chicks or rats. For some hours after you are dead there is still life in your body. But it is not your life, merely the life of your cells. If I had murdered you it would be no defence to point to a culture of your cells and say that you were still alive. There would be life there, but not your life. /

One can kill a rabbit by a blow on the neck and take out its heart. If the heart is kept warm and supplied with the right solution and plenty of oxygen it will go on beating for hours. The heart is alive, though the rabbit is dead. The same is true of human hearts, which have occasionally been taken out and kept alive for some time after their owners' death.

What is this individuality which comes to an end at death? Is it something outside the lives of the parts, and added to them, or is it just the unity by co-operation of these sub-lives? There is good reason to adopt the second view. A tune does not consist of notes and a melody. If the notes are played in the proper order the melody is there. It has no existence separable from its parts. Twenty-two players may or may not co-operate to play

a cricket match, but you certainly cannot have the match without the players.

One cannot reason so directly about a man, because a man consists of a very large number of cells, about ten thousand million million; and no one of them is as essential to the life of the whole man as the bowler to the cricket match. Just as England could carry on without any one man, or any thousand men, so could you without any particular cell or thousand cells. But kill a few million key men, say, all qualified locomotive, lorry, and car drivers, and England would collapse into starvation and anarchy.)

Against the theory that an indivisible something, the soul, leaves the body at the moment of death, is the experience of brain surgery. An American surgeon has studied the effect on several people, including his own sister, of removing large parts of the front of the brain after injury or the growth of a tumour. This causes no appreciable loss of sensation, memory or muscular power, but there is a very real loss of initiative. One patient could look after her household on ordinary occasions, but could not order a large dinner; another could keep a simple job, but could not set about looking for a new one. 'He will never make a revolutionary,' says our author. If fascism proves a success, perhaps this operation will be performed on everyone except dictators.

As the brain is destroyed the personality gradually fades out, until a baby born with no upper parts to its brain shows less signs of consciousness than a fish, let alone a rabbit or dog, though it may live for a year. If there is a detachable soul it can certainly be detached bit by bit, and all that is specifically human in it may be lost long before death. To many it seems more reasonable

to regard the soul as a function of the co-operating brain-cells, just as a concert performance of a symphony, which, like the soul, has a unity of its own, is a function of the co-operating members of an orchestra.

(There are many ways of dying. Usually some organ plays its part so badly that the others are one by one put out of action. In pneumonia the inflamed lungs let through so little oxygen that the rest of the body is suffocated. In heart disease the heart may stop suddenly, or pump so inefficiently as to suffocate the other organs. In many diseases the part of the brain which sends down nervous impulses to the breathing muscles is poisoned, and breathing ceases.)

But science knows nothing of a definite moment of death in most cases. After the last breath a few more minutes of life could generally be vouchsafed by artificial respiration. After the last heart-beat a surgeon could open the abdominal wall and, by putting his hand up into the chest, and rhythmically squeezing the heart, keep the blood circulating for a short time. Death is usually a gradual process, well described by the word 'dissolution'.

(After death of the body as a whole, many individual cells live on for hours or days, till they too die. And is that all? For a man or woman whose interests lie in people and things outside themselves it is very obviously not all. Some religions promise an eternal future life for the individual, though they do not offer a very cheerful prospect to those persons who are most interested in their own individualities. Other religions promise the ultimate extinction of individuality as the greatest possible blessing. I have some sympathy with this view. If I live for another fifty years I expect that most of my acquaintances will be heartily tired of me, and I shall

very probably be rather tired of myself. If we are to believe Freud, we all carry within us a secret longing for death, which at most times we repress below the surface of our consciousness. It is not a hatred of life but a positive desire. And as we grow older we may do well to allow it some measure of freedom. For it is the one desire which will quite certainly be satisfied.

On the other hand, my mind includes certain constituents (this is a clumsy metaphor, but we can only speak of spiritual things in metaphors) which will no more perish with the dissolution of my individuality than will the atoms of which my body is composed. To however slight an extent, I have justice, courage, mathematics, and human kindness, and after my death they will still be manifested in others for whom I shall make room. If these others are better than me I have no cause for complaint. /

(Death, then, as I see it, is the end of a particular pattern of material and mental happenings which are bound up with one another. If the pattern was good and beautiful there is a cause for sorrow; but if, as sometimes happens, the end of the melody of life is its noblest and most beautiful moment, we may feel that 'nothing is here for tears'. We need only pity the dying if they are in intolerable pain, or if their individualities mean so much to them that the prospect of their own end is an agony. For death is not the end of life. It is only the end of my life or of your life.)

KEEPING COOL*

THIS is not a talk about keeping your temper. My title means exactly what it says. We have all been too hot, either with heat from outside on a hot summer day, or from inside after violent exercise or when we had fever during an illness. If a man gets very much too hot he becomes unconscious, and then dies. I am going to tell you why you didn't die on the hottest day of last summer, or after you had played a hard game of football last week. I don't suppose many of you have ever been very hard put to it to keep cool. You probably haven't had to stoke a furnace on a ship, or to work out of doors in India in June or Queensland in January. But the people in places like that find it very difficult to keep cool. If white men cannot solve the problems of keeping cool in tropical Australia perhaps it will be settled by a coloured race which is better equipped for the purpose. So keeping cool is an important problem for the future of the British Commonwealth.

Why must a man keep cool, and keep warm too for that matter? A rise or fall of 10° or 12° F. in the brain temperature is enough to kill him, at least if it lasts more than a few minutes. And in a healthy man or woman the temperature rarely varies as much as 1° on each side of the average. Why is this necessary? Man is a machine, though of course he is also something more than a machine. But most machines don't behave like that. Your watch doesn't stop on a cold day, or run down on a hot one. The reason why plants and animals (including

* Broadcast on British radio.

men) are so sensitive to temperature, is that they are chemical machines. They are not worked by physical forces, like clocks, water-mills, and electric motors, nor by heat, like steam and petrol engines, but by chemical reactions like a motor run off an accumulator. Now a rise of 1° F. in the temperature will speed up the rate of most chemical reactions by about 5 per cent. That is why you have to heat most things before they will burn. Many of them do burn even at ordinary temperatures, but so slowly that we don't notice any great change even within a lifetime.

And the human machine works quicker if the temperature is raised. For example, if you have a fever your heart beats faster. If you time a lot of ants walking along a measured foot their speed is doubled for every rise of 10° F., and by timing enough you can read the temperature within one degree. But man is a very delicately regulated machine, much more so than an ant, and if the machinery runs too fast it breaks down. That is why we have to keep cool.

Now a man at rest produces about 2000 kilocalories of heat per day, that is to say enough to heat 2000 kilograms of water through 1° C. So if a man were put in a large thermos flask and given wet air at body temperature to breathe, so that he could not lose any heat, his temperature would rise by about 2° F. every hour, and he would be dead in about 5 hours. If he were taking exercise the rise would be a good deal quicker.

How do we get rid of this heat at just the right rate? There are three different kinds of regulation. First of all we consciously regulate the temperature of the air next to our skins. In hot weather we put out the fires and open the windows. We take off most of our clothes. If we have

an electric fan we turn it on. That sounds obvious. But there is one group of human beings who can't regulate their temperature in that way, namely, babies. A certain number of them die every year as a consequence of being too hot in summer, because their mothers have not regulated their temperature for them.

After voluntary regulation comes regulation by the blood-vessels. The hot blood from inside the body comes to the skin, loses heat, and goes back cooler, just as the hot water from the engine of a motor-car gets cooled in the radiator. There are small muscles round the arteries going to the skin. When they are contracted, not much blood flows through the arteries. When they relax, the flow through the skin may be increased ten times. You can see it getting redder. Of course they don't contract or relax of themselves. They are controlled by special nerves, and messages to the muscles are sent down the nerves from the brain. They come from a part of the brain not concerned with consciousness or will, near to the parts which regulate our hearts, our breathing, and our digestion.

If we still can't lose enough heat by opening these blood-vessels, we fall back on our third line of defence, namely, the sweat glands. We have something like a thousand sweat glands opening on every square inch of our skin, more in some parts and less in others, and they are controlled, like other glands, by nerves. But like most glands, they are not subject to the will. The chief exception to that rule is, of course, the tear glands. We mostly learn to stop ourselves weeping, and some people can weep when they want to.

Some animals, such as horses and cows, are provided with sweat glands like ourselves, and keep cool in the

same way. Others, such as dogs and cats, have no sweat glands except on their noses and on the palms and soles of their feet. Instead of sweat glands the dog uses his salivary glands. Two different nerves go to them, and according to which nerve transmits messages from his brain to his mouth he produces a different kind of saliva. When he eats he secretes a little of a rather sticky kind. When he is hot he secretes a lot of a watery kind. He also starts panting, which helps the saliva to evaporate, just as it would help your sweat to evaporate if you turned on an electric fan. So the dog keeps cool with his mouth as men and horses do with their skins.

How does sweating keep us cool? It is not enough for our skins to be wet. The water must evaporate. It takes about 576 calories to turn 1 gram of liquid water into vapour at body temperature. So a man could get rid of 2900 kilocalories a day, which is about what an average town-dweller produces, by evaporating 5 litres, or just over a gallon, of sweat.

If you want to try how efficient evaporation is for cooling, take two tins wrapped round with cloth, and fill them with hot water. But have one cloth dry, and wet the other. You will find that the tin in the wet cloth will cool at least twice as fast as the other.

The real test of our cooling powers comes either when the air is much hotter than our bodies, or when it is so saturated with water that the sweat can't evaporate, and merely runs uselessly down our skins. It is amazing what great heat we can stand provided the air is dry. The first man who investigated just how high a temperature he could stand was Mr. Blagden, who was Secretary of the Royal Society towards the end of the eighteenth century. He went into a room heated to 260° F., which is 48°

above the boiling-point of water. He stayed there for over three-quarters of an hour, during which time a beefsteak was not merely roasted, but baked till it was quite hard. He took in a dog, which was kept in a basket so as not to burn its feet, and the dog managed to keep cool too. To show how evaporation cools things, he took in two pots of water. On one he dropped some wax, which melted, and prevented water vapour from escaping. The temperature of this pot rose much more than that of the one with a free surface.

Several people have repeated this experiment in recent years. Professor Moss of Birmingham also took a beefsteak with him, but when he came out his clothes were wet with perspiration, and unfortunately while he was changing the cat got the steak, so he never found out if it was really well cooked. My father found he could stand dry air up to about 300° F., but if he moved about too much his hair began to singe.

Now all these experiments were done in dry air. Wet air is a very different story. In air at body temperature which is completely saturated with water one sweats vigorously, but it is no use. No water evaporates, and the body temperature rises by 2° or 3° F. per hour. I have once been in saturated air at 120° F. It was terrible. Every breath heated my throat and lungs. We had clinical thermometers, and every minute we took them very quickly out of our mouths and read them in cold water. For, of course, in the air they would have gone up at a great rate. Our temperature rose nearly a degree a minute. I stayed in for a very short time. One of my colleagues was braver, and stayed in till his blood temperature was 105° .

The object of these experiments, and of course of a lot

of others at lower temperatures, was to see what conditions are safe for workers. Safety and comfort do not depend on the temperature as measured by an ordinary thermometer. But wrap the bulb in a piece of wet cloth, and you get what is called a wet-bulb thermometer. If the air is very dry, this can keep fairly cool. For example, in Australia, even in the South, the dry bulb may read over 110° in the shade. But under these conditions the air is so dry that the wet bulb may read 70° or less, and people can play in test matches quite as comfortably as on a sweltering July day in England when the dry bulb reads only 90° , but the air is so wet that the wet bulb reads 70° .

That is not the whole story. If the air is moving, this helps to evaporate sweat, and keep us cool. But in very hot dry air quite a slight breeze is enough to do this, and a strong wind heats the body. That is why Arabs need woollen cloaks to shelter themselves from the hot winds of the desert.

Sunstroke is probably due to overheating of the brain or the spinal cord, and has nothing to do with the sun's rays, as such. I proved this to my own satisfaction in the following way. I was in Egypt in August 1918 in a camp near Alexandria. Every day I went out and sat on the beach in a bathing dress with no hat, and let the sun shine on my head for a couple of hours, pouring water on to keep it and my back cool. I never got even a headache. But I got a blister that reached from one elbow to the other across my back. That is an effect of light, not of heat, and it would not have happened if my skin had been brown like an Egyptian's. On the other hand, I should certainly have got a headache and might have died of sunstroke if I hadn't kept my head cool.

It gets hotter as one gets down towards the centre of the earth, so deep mines are always hot. But coalmines have to be well ventilated, to blow out the explosive gas that comes from the coal. So coalminers, except in a few mines, don't suffer much from heat. But the deeper Cornish tin mines, which are now abandoned, used to be rather badly ventilated. The men working near the bottom used rock-drills worked by compressed air. The expansion of this air cooled it down a bit, but even so they often could not work for more than half an hour at a time. Then they used to go and cool themselves at the bottom of a shaft where air was descending.

Cooling is one of the big problems of the Rand goldmines in South Africa, some of which are over a mile deep. The quartz dust raised by drilling and blasting is poisonous if breathed. So to keep it down the air has to be kept wet, and consequently loses its cooling power. If these mines are to go much deeper, and therefore into hotter rock, the engineers will have to cool the air artificially, or to find some other way of keeping the dust out of the miners' lungs.

When a man sweats he loses water, and also salt. Your sweat may contain up to $\frac{1}{2}$ per cent. of salt, so if a miner loses 18 lb. of sweat in a shift, as miners have done, he is short of nearly an ounce and a half of salt. This is a lot, as you will see if you weigh it out and try to eat it. The miners naturally drink water to quench their thirst, and they develop a craving for salt. The miners in the deep English mines eat far more bacon and kippers than those in the shallower ones. But even so they may run short of salt.

It is just the same in hot countries. Salt is more or less of a luxury in England. But most of us could do without it, at least in winter. But it is a necessity of life in India.

That is why some people think that a tax on it is unfair. Men who run short of salt through sweating are very liable to get cramp in their muscles if they work hard. The stokers on ships often go down with cramp for this reason. A doctor in the Faroe Islands found that British stokers were more liable to cramp than Norwegians or Danes, because they ate fresh meat and fish, while the Scandinavian stokers lived largely on salt fish. And Englishmen who go to hot countries often seem to suffer in health until they learn to take a great deal more salt than they needed at home.

We have a lot more to learn about keeping cool. We don't know why some people stand heat so much better than others. And we know very little about the effects of intense sunlight on Europeans. Even if they live in properly designed houses, wear sensible clothes, eat a suitable diet, and do not get malaria or other tropical diseases, some Europeans seem to be unhealthy in the tropics. Perhaps the sunlight has a bad effect on them. Some people believe that English people can live all their lives in the relatively cool uplands of Kenya and Northern Rhodesia. Others say that children brought up there grow tall, but thin and weedy. I don't pretend to know the truth. But I am sure we ought to find out as quickly as possible, and frame our policy accordingly.

I am sure that you can all think of a great many other biological problems raised by our world-wide Empire. There is the problem of race-crossing, the problem of tropical diseases, the problems of tropical agriculture and stock-breeding, and many more. I have told you a very little about one of the simplest of these problems. Perhaps some of you will tackle the more complicated and difficult of them.

WORK IN COMPRESSED AND RAREFIED AIR*

I WONDER whether you think of a physiologist like me as sitting at a laboratory bench doing experiments with very complicated apparatus on a frog's heart or a sprouting barley corn. Of course we do that kind of thing, but we also do quite simple experiments on ourselves and other people, in conditions much more exciting than those of the laboratory. To-day I am going to tell you how physiology has been applied to save the lives of men who have to work in air at abnormal pressures.

First of all I will talk about work in compressed air. There is only one reason why men have to work in it, and that is to keep out water. The men who tunnel through the London clay to make our underground railways have to work in compressed air to keep the water from flooding the tunnel. The air which is pumped down to a diver has to be compressed in order to get it down the pipe to him. The greater the depth the greater the pressure. For every 30 feet of salt water or 33 feet of fresh water an extra atmosphere's pressure is needed. So a diver at 330 feet below the sea, which is the greatest depth reached in an ordinary dress, is under a pressure of 12 atmospheres, one due to the air and 11 to the water.

Now let us see what his dangers are. One of the simplest is that the pump which compresses the air sent

* Broadcast on British radio.

down may leak at high pressures, so that he is suffocated, or at best very short of breath. But let us suppose he has a good pump and plenty of power to work it, what next?

Thirty years ago people thought that the extra pressure was dangerous in itself, and divers were provided with wicker-work baskets like crinolines to keep the water pressure off their bodies. Of course it sounds very alarming to hear of an extra pressure of 150 lb. per square inch, or 10 tons per square foot, but we have to support one-tenth of that pressure in ordinary life, and don't notice it. Nor does the diver. What damages the human body is not pressure, but differences of pressure. For example, if the diver had only one atmosphere's pressure inside his lungs and 10 outside, his chest would cave in.

The only place where difference of pressure is likely to hurt a diver is in the ears. On one side of the ear-drum there is a tube communicating with the outside, on the other a tube called the Eustachian tube, leading into the throat. If the pressure on the two sides is unequal you get first discomfort, then pain. The underground railway worker can equalize the pressure on the two sides of his drums by shutting his mouth, holding his nose, and blowing. If you do that you will feel your Eustachian tubes blown out, and hear a clicking noise in your ears like the noise when you swallow. The diver has a glass window between his nose and his fingers, so he has to open his Eustachian tubes by swallowing. If the diver has a bad cold his Eustachian tubes may get blocked, and if in spite of this he goes down, he may burst one or both ear-drums, which is very painful, and makes him deaf till they are mended.

It is quite easy to learn in a compressed-air chamber

how to open your Eustachian tubes, and once this is learnt you can go down as fast as you like. At one time divers were supposed to go down very slowly. This is quite unnecessary. My first experience of diving was when I was 13 years old. My father was investigating the physiology of diving for the Admiralty, and in order to demonstrate the safety of rapid descent by untrained people, he offered me up, like Isaac, or more accurately, down. I stayed down for about half an hour at 40 feet after one lesson in Eustachian tube opening in a compressed-air chamber. This was a little more exciting than it sounds, because the diver's hands are free and the water is kept out of his dress by rubber cuffs. As my wrists were too small for the cuffs, the water came in, and by the time I came up, it was up to my neck. Of course the air which was pumped down to me prevented it rising any higher, but I was very cold indeed.

The diver is generally safe enough on the bottom, but when he comes up care is needed. His danger is from bubbles which may form in his blood or tissues when the pressure is taken off, just as they form in a bottle of lemonade or soda water. There is a story that when one of the first tubes was being driven under the Thames, the directors of the company celebrated its arrival under the middle of the river by having lunch in the tunnel. They went into an air lock, the steel door was shut behind them, and the pressure raised till it reached that in the end section of the tunnel. Then a door at the other end was opened, and they went on to lunch. As you know, company directors always have champagne for lunch, and these were no exception to the rule. But when the bottles were opened the champagne did not fizz. The pressure outside the bottles was as big as that inside

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them. However, the directors drank the wine. After lunch they went back to the lock, and the pressure was lowered. They soon began to feel very uncomfortable. As the pressure fell the wine began to fizz, and the financiers to suffer from inflation !

The bubbles in divers are not of carbon dioxide, as in champagne, but of nitrogen. All the time that they are breathing compressed air, their blood takes up more nitrogen and oxygen than usual. The oxygen is used up, but the nitrogen goes into the tissues, especially into fat, and tissues like nerve and brain, which contain a great deal of oil in which nitrogen dissolves easily. If the pressure is taken off too quickly, bubbles may be formed. If they form in nerves the strain on the fibres causes pain, paralysis, or both. If in the blood, the vessels of the lung or heart may be blocked, and the diver loses consciousness and may die in a few minutes.

There are two ways of dealing with this trouble; prevention and cure. The diver must stay as short a time as possible at the bottom if he is going deep. For example, only 12 minutes are allowed at 200 feet. He then comes up about half-way to the surface. If he came too far he would be in danger of bubbles; if he did not come far enough he would still be absorbing more nitrogen than desirable. He stays at this pressure for a certain time and then comes up by stages which have been calculated, and the calculations checked by experiments first on goats, and then on men, particularly on Commander Damant and Lieutenant Catto, R.N.

But a diver may get entangled at the bottom and stay too long, or a mistake may be made in timing, so that symptoms develop. If so he must be recompressed, so as to make the bubbles get smaller, and finally dissolve

again. A diver who had come up too quickly went black in the face and lost consciousness on reaching the surface. His helmet was screwed on and he was dropped overboard. The bubbles in his blood soon dissolved again, and he was able to answer the telephone and to come up safely after waiting for the proper time.

However, it is much better to have a steel chamber at the surface in which men may be recompressed if they develop any symptoms.

To get up the German battle fleet which was sunk in Scapa Flow it was necessary first to send down divers to fix tubes to the bottoms of the ships, which had all turned over, and then to pump air down these tubes into the hulls. Other workers went down the tubes into the insides of the ships to close doors between different compartments so that the air could be pumped into the various parts of the ships in the right amounts. Mr. Mackenzie, the engineer in charge of the works,* had three compressed air chambers on the salvage ships and two on shore, to deal with cases of illness, and though there were a number of cases, all recovered very quickly when put into compressed air.

There is one other danger to which divers are exposed, namely, oxygen poisoning. For oxygen, like other good things, is a poison if you have too much of it. A man breathing pure oxygen at ordinary pressure, or air at five atmospheres, which comes to the same thing, will get pneumonia after a day or so. Pure oxygen at three or four atmospheres causes convulsions, and at lower pressures probably affects the brain a little after some time. So a diver who has been down too long has to

* Readers will remember his remarkable evidence in the *Thetis* case.

choose between the danger of bubbles if he ascends too quickly, and oxygen poisoning if he ascends too slowly. Perhaps in future it may be desirable to dilute the air with nitrogen at very high pressures.

In theory all these dangers can be overcome by sending the diver down in an armoured dress which will withstand the water pressure, even though the air inside it is not compressed. Such dresses exist, and were used by the Italian divers who salvaged the gold from the *Egypt*, a ship sunk too deep for the ordinary divers to reach. Unfortunately such dresses are so clumsy that the diver cannot work so quickly or accurately as in a flexible dress. Their main value has been for observation. But perhaps some day they will be developed so as to supersede the ordinary kind of dress for many purposes.

Just as the pressure rises when you go down it falls when you go up. At 18,000 feet the pressure is half that at ground level, at 34,000 it is one quarter, and so on. As the height increases in arithmetical progression the pressure falls off roughly, though not quite, in geometrical progression. So airmen, whether in aeroplanes or balloons, are exposed to low pressures. You might think they were in danger of bubbles, like divers during their ascent. So far there have been no casualties from this cause, because aeroplanes do not rise quickly enough, but some of our latest interceptors must be getting very near the danger point.

The airman or balloonist is however in peril from want of oxygen. At 18,000 feet a cubic foot of air contains half the weight of oxygen that the same volume contains at sea level. Very well, then, why shouldn't the airman breathe twice as deep or twice as fast? He is sitting still, so it would not be difficult. Unfortunately that won't work

because the amount of oxygen that the haemoglobin in the blood will take up depends on the partial pressure of oxygen in the lungs, that is to say, the fraction of the total pressure which is due to oxygen; and extra ventilation of them is no help.

Before we see how the airman copes with this problem, let us see why even slight oxygen want is dangerous. Instead of going in an aeroplane we will go round to Messrs. Siebe Gorman & Co., the diving-dress makers in Westminster Bridge Road, London, and ask if we may borrow their pressure chamber, which can be used for high- or low-pressure experiments. We go in, the door is bolted behind us, and the pump starts working. As the pressure falls it becomes cold and foggy. The reason is obvious. The air which leaves the chamber is not really pulled out by the pump, but pushed out by the air which remains behind. So this air is doing work, and the only available source of energy is its heat.

We stop at a pressure of half an atmosphere, corresponding to 18,000 feet. For a minute or two we breathe a little faster than usual, but this soon passes off. I feel grand, and tell you so. But I notice you are not too steady on your feet, and making silly jokes. Curiously enough you have just the same experience about me. The symptoms of oxygen want are very like those of alcohol poisoning. If we stayed for several hours at this pressure we should get bad headaches and vomit. At lower pressures still one becomes unconscious, and unacclimatized people die at heights well below that of Mount Everest. None of these things happens if one breathes oxygen, so they are clearly effects of oxygen want, and not of low pressures.

The danger for an airman is obvious. Even at 12,000 feet his judgment and skill may be a little below normal,

like those of a motorist who, though not drunk, has 'had one or two'. Higher up the danger is far greater. Two French balloonists who went up in 1875 with oxygen to breathe, died because they felt so well that they did not trouble to breathe it until their arms were paralysed and they could not reach for their oxygen apparatus. So the airman must have a supply of oxygen, and must obey orders as to breathing it, even when he is sure they are quite unnecessary.

His engine suffers in the same way as himself, but that is soon remedied by supercharging, that is to say, compressing the air which is supplied to it. During the war a distinguished officer of the Royal Engineers suggested that airmen should be given compressed air to breathe. Of course the effect of this would have been to burst their lungs. They sometimes start leaking in trumpeters who blow too hard.

Up to 30,000 feet or so it is quite sufficient if a certain amount of oxygen is added to the air which the airman breathes. At greater heights he must breathe pure oxygen. But at over 40,000 feet, when he is getting near the stratosphere, even this is not enough. If you breathe pure oxygen at one-fifth of an atmosphere's pressure, i.e. about 38,000 feet, you will take in almost as much per breath as when you are breathing ordinary air at ground level. For the air contains one part in five of oxygen. Once you go much above this height you will suffer from oxygen want, even when breathing pure oxygen.

To go higher than this the airman must breathe, not merely oxygen, but oxygen under a higher pressure than the air outside him. If his lungs are not to burst he must have the same pressure outside his chest. This can be achieved in two ways. He may go up in a closed chamber

like the aluminium ball of Professor Piccard's balloon. This is all right for a balloonist, and perhaps for passengers in an aeroplane, though it is bound to be rather heavy.

The other alternative is a pressure suit in which the airman is completely enclosed. The air in this is automatically kept at a pressure above that of the outside air. It is rather clumsy; however, he can move about and attend to his engine. The suit may be covered by several layers of aluminium foil to protect its wearer against the cold.

These pressure suits were originally designed for balloon work. Later they were adapted for flying, and were used by the British airmen who now hold the height record. If men ever get to the moon, where there is no air at all, they will be essential there. Whereas on Mars or Venus, although the air would be poisonous, the pressure seems to be high enough to make something like a mine rescue apparatus, in which oxygen is breathed at the pressure of the external air, suitable for explorers.

However, I haven't time to go into the question of work in poisonous atmospheres, and I have given you a rather simplified account of work at high and low pressures. For of course there are some extras to consider. The diver may have to work in total darkness, and even inside a sunken ship. He has to communicate with the surface by telephone, or if this breaks down, by pulls on the tube which supplies his air. In a few cases, a diver may have to use a self-contained dress, carrying his own supply of oxygen or air, instead of having air pumped down to him. This is particularly so if he has to go into a flooded mine or tunnel, as the divers did when the Severn tunnel was flooded.

This means that his oxygen or air supply must be very carefully regulated. However, the physiological problems are the same. I only wish that as much work had been done on the physiology of men in other dangerous occupations, for example tool-grinders and sand-blasters who breathe poisonous dusts. Modern industry is constantly exposing people to abnormal conditions, and it is up to us physiologists to find out how to make them healthy. But we can only do this if the workers or employers ask us to do so. And this will only happen if enough people understand that physiology is not just a laboratory science, but something applicable to your everyday lives.

SOME ADVENTURES OF A PHYSIOLOGIST*

SCIENTIFIC research is always exciting to the men and women who do it, at any rate when they get definite results from their work. But it isn't always exciting to outsiders. Intellectual adventure is the hardest kind to share. However, a few scientists manage to combine intellectual and physical adventure. My father, Dr. J. S. Haldane, who died in March 1936, was one of this kind. As I helped him with his work, mainly as a bottle-washer and a calculator, for a good many years, I am going to talk mainly about his work rather than my own.

It is just fifty years ago that he started working on a fairly straightforward problem: 'What is bad air? What makes air dangerous to breathe? And how can its bad effects be prevented?'

He started work in Dundee. He collected samples of the very worst air that he could find. He went, between 12.30 and 4.30 in the morning, to the worst slums, taking samples of air from rooms where as many as eight people were sleeping in one bed. He went down the sewers also. Many years later I was with him in Dundee, and to remember his way about above ground, he had to imagine himself back in the sewers below the streets.

The results of this investigation were quite negative. There was a slight drop in the oxygen of the air and a slight increase of carbon dioxide, as compared with out-

* Broadcast on the British radio.

side air. But these were not enough to affect the health. As for bacteria, there were generally fewer in the air of a sewer than in that of the street outside. Nor could any poisonous volatile substances be found in the air. We know now that the bad smells due to overcrowding of unwashed people and to open drains are harmless in themselves. But they are valuable warnings. Unwashed men and women are likely to be lousy, and lice carry typhus fever. Open drains allow flies to carry bacteria of various kinds onto food.

My father was a very obstinate man, and his failure did not daunt him. He built a wooden chamber with a floor three feet by four feet, and six feet high. It was lined with lead so as to be airtight, and the door had rubber flanges to render it airtight also. The person inside could be watched through a window, and samples of gas could be taken through a small tube. In this chamber he or his colleague Smith were shut up, sometimes for as long as seven and a half hours, until the air really did get bad. After three or four hours there was violent panting, which became worse and worse, then headache, and later vomiting.

What had made the air so bad? It was not a matter of heat or moisture. The oxygen had fallen from 21 per cent to about 13 per cent, the carbon dioxide had risen to $6\frac{1}{2}$ per cent, and there were small traces of volatile substances, some of them smelly. Which was responsible for the panting and headache? To eliminate the carbon dioxide he went in with a tray of a mixture of slaked lime and caustic soda. After two or three hours the oxygen had fallen so low that a match simply fizzled and would not light. But there was no panting or distress in seven hours. The oxygen of the air might be raised

above normal, but if carbon dioxide accumulated there was still panting. Want of oxygen alone caused some panting, but much less. He just became blue and fell down unconscious. If the carbon dioxide is constantly being removed and the oxygen replaced, a man may stay indefinitely in a very small space. This principle is now universally recognized and applied to mine rescue apparatus, submarines,* and so on.

All this sounds very simple and straightforward. But it was not simple at the time. One group of physiologists claimed to have breathed a mixture containing 20 per cent of carbon dioxide without harm. Others felt ill in 1 per cent. Probably neither could analyse a gas mixture. It is useless to do experiments of this kind unless you have a really accurate apparatus and can use it. My father designed and made an apparatus for this purpose, but it took him a number of years of hard work. A whole day might be spent in tracking down a leak. Weeks were spent in trying out various different strengths of pyrogallol solution in potash till he got the one which absorbed oxygen quickest.

Finally the apparatus was very large and cumbrous; all very well for laboratory work, but much too big to take down a mine. However, it was easy to get samples of mine air and analyse them in the laboratory. Of course, in order to get really bad air he had to go into the worst ventilated parts of mines, and especially into parts which are no longer worked, and therefore not ventilated at all. Only later on did he make this apparatus small and portable.

I remember going with him into an old pit in North

* I was wrong here. The evidence in the *Thetis* case showed that the authorities had given up the use of soda-lime.

Staffordshire. We were let down the shaft, not in a closed cage like a lift, but sitting in a large bucket slung on a chain. The air was, however, fairly good, because some of the air from a part of the mine which was still being worked came up this shaft.

We walked a little way, and then crawled along an abandoned road. The tunnels leading from the shaft to the working face in a colliery are called roads, though even the best of them would not pass as a road above ground. After a while we got to a place where the roof was about eight feet high and a man could stand up. One of the party lifted his safety lamp. It filled with a blue flame and went out with a pop. If it had been a candle this would have started an explosion, and we should probably have been killed. But of course the flame of the explosion inside the safety lamp was kept in by the wire gauze. The air near the roof was full of methane, or firedamp, which is a gas lighter than air, so the air on the floor was not dangerous.

To demonstrate the effects of breathing firedamp my father told me to stand up and recite Mark Antony's speech from Shakespeare's *Julius Caesar*, beginning: 'Friends, Romans, countrymen.' I soon began to pant, and somewhere about 'the noble Brutus' my legs gave way and I collapsed onto the floor, where, of course, the air was all right. In this way I learnt that firedamp is lighter than air and not dangerous to breathe.

There is another much more dangerous kind of bad air, called blackdamp, or bottom gas, which consists of air in which the oxygen has been wholly or partly replaced by carbon dioxide. It is heavier than air, so it accumulates at the bottom of shafts and other holes, and people who breathe it fall down and die, unless they are rescued at

once. These facts were discovered as the result of a great many analyses, and it may be imagined that my father and the mining engineers and inspectors who took the samples did not get them without running some risks.

There is a third kind of bad air, also found in coal-mines, which has killed a great many more miners than the other two kinds which I have mentioned. This is afterdamp, the gas mixture found after an explosion. It used to be thought that most of the men killed in a colliery explosion died from its mere force. After reading accounts of explosions, and particularly of the poisoning of rescue parties, my father came to the conclusion that they were killed by carbon monoxide. So before he visited mines which had recently exploded, he worked for two years on its properties as a poison.

It was known that it acted by uniting with haemoglobin, the red pigment in blood, so as to make it useless for carrying oxygen, but nobody had much idea as to how quickly a given amount in the air would kill a man. He started by finding out what proportion in the air would kill a mouse. He found that about one volume added to 500 volumes of air would do so. On the other hand, since it acts by cutting down the oxygen supply, oxygen is an antidote to it, and a mouse will live in a mixture of one volume of carbon monoxide with 30 volumes of oxygen. Insects have no haemoglobin. They breathe by little tubes called spiracles leading into their tissues. So carbon monoxide does not harm them. My father found that a cockroach would live for a week in a mixture of four parts of carbon monoxide with one of oxygen.

He then began to experiment on himself. He found that he could stay indefinitely in air containing one

volume of carbon monoxide in 2,000. When he breathed one part in 500, which knocked a mouse out in four minutes, he noticed no effect in the first half-hour. But after 71 minutes the experiment was stopped. His notes read: 'Vision dim, limbs weak. Had difficulty in getting up or walking without assistance. Movements very uncertain.'

From these experiments a simple principle gradually emerged. A mouse is no more sensitive, in the long run, to carbon monoxide than a man. But the mouse is much more rapidly affected. The reason is simple. All warm-blooded animals produce about the same amount of heat per unit of surface. Three thousand mice weigh as much as one man, but have twenty times his surface area. They therefore produce twenty times as much heat per minute, and need twenty times as much oxygen. Similarly they take up carbon monoxide at twenty times the rate.

So a mouse or a small bird can be used as an indicator of the presence of carbon monoxide. Such an indicator is badly needed, for carbon monoxide has practically no smell, nor does it cause any irritation, like the poisonous war gases. So a man, or for that matter a bird, feels nothing till he falls down.

After making these discoveries, and inventing methods for determining the amounts of carbon monoxide in air and blood, my father was ready to go down a mine that had exploded. He had not long to wait. In January 1896, 57 men and 30 horses were killed by a colliery explosion at Tylorstown, in South Wales. My father went down the day after the explosion. He found that only 5 men had been killed by the force of the explosion. The others had been poisoned by carbon monoxide. The same thing happened at other explosions.

For the next thirty years my father was constantly going down mines of all sorts, devising methods for improving ventilation, preventing explosions, and rescuing men when an explosion had occurred. I have no time to tell of this work. I am going to talk about some of his physiological discoveries.

He determined to find out why we breathe. Now in biology 'Why?' has two kinds of answer. He knew already that we breathe in order to absorb oxygen and get rid of carbon dioxide. That is what is called a final cause. But it was not known what makes people breathe. Why does the brain send messages along the nerves to the breathing muscles about twenty times a minute? This is the efficient cause of breathing, the second kind of answer to the great question 'Why?'

He needed exact records of the breathing when different kinds of gases are inhaled. So he made a wooden box shaped rather like a coffin—in fact, we called it the coffin. A man was put in it with his head sticking out through a rubber collar, and the whole thing was airtight. A tube came out of the box to a drum which rose when he expanded his chest and so forced air out of the coffin, and fell when he breathed out and therefore sucked air back. A lever attached to the drum wrote on smoked paper, so one could measure the exact amount of air breathed. Then the man was given a series of gas mixtures and records taken.

I spent some time in this coffin, for ever since I was about four years old, my father used me for experiments. It was found that quite a little carbon dioxide added to the air breathed increased the depth of breathing. The subject might not notice anything, but the record showed it. On the other hand, want of oxygen, unless severe,

had very little effect; so it became clear that the breathing was governed by carbon dioxide rather than oxygen.

Working with a colleague called Priestley, he next found that if you breathe out a deep breath quickly, so as to squeeze out the air which is at the bottom of the lungs in equilibrium with the blood, the amount of carbon dioxide in it is very constant, though the oxygen may vary. Breathing is regulated so as to keep the carbon dioxide in the alveolar air, as it is called, steady.

He and Priestley went to the top of Ben Nevis and to the bottom of the deepest mine in England, and they found more carbon dioxide in the alveolar air on the mountain, and less in the mine. When they worked out the figures they found that the weight of carbon dioxide in a given volume of alveolar air did not change with the pressure, though the percentage was larger in the thin air of the mountain than in the thick air underground. This meant that the amount dissolved in the blood stayed constant.

Now it was clear that the carbon dioxide in the blood stimulated the brain to send down messages to the breathing muscles. But it was not clear whether it did so because it makes the blood more acid when it dissolves in it, or for some other reason. So I started some experiments, with a colleague called Davis, to find out.

First of all we had to learn how to estimate the amount of sodium bicarbonate in blood. This is not very easy. It took us three months' practice before we could get duplicate analyses to agree. Then we argued like this. If the breathing is regulated by the acidity of the blood, then when we increase the amount of the alkaline bicarbonate in it, the breathing will slow down so as to

keep in more carbon dioxide to balance it. And if we diminish the amount of bicarbonate, the breathing will speed up so as to lower the amount of carbon dioxide, and keep the balance true.

It was fairly easy to get the bicarbonate up. We ate about an ounce and a half of bicarbonate of soda, and, sure enough, our breathing slowed down, and the carbon dioxide in our blood rose to balance it. But it was more of a job to get it down. The obvious way was to drink hydrochloric acid (commonly called spirits of salts). Of course this is a corrosive poison and burns your mouth and throat when strong, so I had to dilute it; but even so I found I couldn't drink enough to have much effect.

So I worked out a number of chemical tricks to smuggle hydrochloric acid into my blood disguised as something else, so to speak. The best of these tricks is to drink a solution of ammonium chloride. It mustn't be too strong, or it makes you vomit, and you mustn't take too much, or you die.

When the ammonium chloride is absorbed from your intestine it goes to your liver, and the liver turns the ammonia into a harmless stuff called urea, leaving the acid behind. An ounce or two of ammonium chloride liberated enough acid to make me very short of breath. I panted for several days on end, and a number of curious things happened in my body with which I need not trouble you.

Much to my surprise, this discovery was some use. A German doctor called György, who is now a refugee in England, had found that a particular kind of fit which some babies get is due to the blood being too alkaline, and was able to cure them with ammonium chloride.

Since then a better cure has been found, but probably he saved a few lives and a good deal of suffering.

You see, then, that we have got rather a long way from my father's air analyses in the Dundee slums. But each step followed logically from the one before. And each was only made possible by a great many very accurate measurements made with special apparatus designed for the purpose. It is easy enough to ask such a question as 'How is breathing regulated?' But if we want an answer from nature we must put our question in acts, not words. And the acts may take us to curious places. Some questions were answered in the laboratory, others in mines, others in a hospital where a surgeon pushed tubes into my arteries to get blood samples, others on the top of Pike's Peak in the Rocky Mountains, or in a diving-dress at the bottom of the sea.

That is one of the things that I like about scientific research. You never know where it will take you next.

DARWIN *

YOU care for nothing but shooting, dogs and rat-catching, and you will be a disgrace to yourself and your family,' said Dr. Robert Darwin, of Shrewsbury, to his son Charles, about 110 years ago. Certainly Charles showed little interest in Latin and Greek, the only subjects taught him at school. He did not do much better as a medical student at Edinburgh. His lectures bored him, but he began to find things out for himself. His first scientific paper, read when he was 16 years old, contained the discovery that what had previously been called the eggs of *Flustra*, an animal which forms incrustations on seaweed, could swim about, and were really larvae.

He had no liking for a medical career, and when 19 years old was sent to Cambridge to become a clergyman. Once again he did not care for lectures, but showed great ~~X~~ zeal in collecting beetles. At 22 he left with a pass degree, and soon afterwards accepted an unpaid post as naturalist on H.M.S. *Beagle*, whose voyage round the world lasted for five years. He was, however, able to get ashore for weeks at a time, especially in South America. He interested himself in geology and in collecting and describing hitherto unknown animals.

And what he saw started him thinking. He visited islands whose geological structure showed that their rocks had once formed part of the sea bottom, and yet were inhabited by animals found nowhere else, though resembling those on the neighbouring continent. On the

• Broadcast on the British radio.

prevailing theories these animals must have been specially created. At that time most biologists thought that every species of animal had been created by God in its existing form, and many believed that all animals were descended from ancestors in Noah's ark. Darwin found these ideas difficult.

'It is strange,' he wrote from St. Helena in 1836, 'that this little centre of a distinct creation should, as is asserted, bear marks of recent elevation.' He did not yet see how to explain such facts. But on some human affairs he had certainly made up his mind. His letters are full of attacks on slavery, which was only abolished in the British Empire in 1838.

I was told before leaving England [he wrote from South America] that after living in slave countries all my opinions would be altered; the only alteration I am aware of is forming a much higher opinion of the negro character. It is impossible to see a negro and not feel kindly towards him.

On the other hand, he did not take to the savages of Tierra del Fuego. But he seems to have liked every other human race.

I much suspect [he wrote from Sydney] that those who have abused or sneered at the missionaries, have generally been such as were not very anxious to find the natives moral and intelligent beings.

He returned to England in 1836, and never left it again, partly because of persistent bad health. In 1837 he started his first notebook on the transformation of species, that is to say, the theory that existing species of plants and animals, including men, were descended from ancestors very unlike themselves, and that the change, or evolution, had been mainly due to the survival of the

fittest in each generation. His great book, *The Origin of Species*, was published twenty-two years later. During the whole interval he went on collecting facts for and against the theory which he gradually built up. In doing so, he says:

I followed a golden rule, namely that whenever a published fact, a new observation or thought came across me, which was opposed to my general results, to make a memorandum of it without fail and at once; for I had found by experience that such facts and thoughts were far more apt to escape from the memory than favourable ones.

In other words Darwin was about as intellectually honest as it is possible for a man to be.

What other good qualities had he? Again to quote from his own words, 'I think that I am superior to the common run of men in noticing things which easily escape attention, and in observing them carefully.' We are apt to forget that if Darwin had never written a word on evolution, he would still have been among the world's great biologists.

He wrote a number of books on the fertilization of flowers. They describe both observation and experiment. It is characteristic of Darwin that his experiments were always very simple. When one reads them one is inclined not so much to say 'how clever Darwin was to think of that', but 'how stupid the rest of humanity was not to think of that before'. For example, he noticed that there are two kinds of primrose and cowslip, one with long styles, and the other with short. He fertilized numbers of flowers with the pollen of others, and found that pollen from long-styled plants produced plenty of seed on short-styled plants, and similarly pollen from short on long-

styled plants. But when he crossed long with long, or short with short, he got very few seeds.

Next spring have a look at a few primroses and cowslips to see the two forms, and in August try to pick some purple loosestrife, which has three different forms of flower whose peculiar marriage system Darwin studied. Then you may care to read Darwin's book, *The Different Forms of Flowers on Plants of the Same Species*. In this book he nearly discovered what are now called Mendel's laws of heredity. His own experiments on the inheritance of the flower forms in the primrose agree with these laws. Unfortunately his modesty led him to include with his own some experiments by a German botanist called Hildebrand, which had certainly been carried out carelessly, and do not agree with Mendel's laws.

His last book, published when he was 72 years old, was devoted to earthworms, but he had been studying them for at least 42 years. He points out that they are constantly raising earth from below the surface, and may bring up a layer a foot deep in 60 years. This process serves to bury large stones and even buildings in the course of time. Among other experiments he did a large number of intelligence tests on worms, finding, for example, that they pulled triangular pieces of paper into their burrows by the sharpest angle, but pairs of pine needles by the blunt end. He was convinced that worms had intelligence.

Here he may have been biassed by his genuine love of animals. He was fond of shooting when young, but soon gave it up for observation, which demands as much skill, and a lot more patience. His son described an occasion when he stood so still that some young squirrels apparently took him for a new kind of tree, and ran up his legs

and back, while their anguished mother barked at them from a real tree.

In his scientific work he was guided by two principles. He never forgot that everything has a history. For example, the soil of England has been made by earthworms, and men have been evolved from animals. And he was always trying to break down barriers between groups of living beings which in our ordinary thought we regard as totally distinct. He devoted two books to the movements of climbing plants, and the even quicker movements of those which catch insects. In these he points out that many plants have properties which are usually thought to be peculiar to animals. In consequence he was not ashamed of making what he called 'fool's experiments', as when, after noticing that a plant responded to vibrations of the table, he made his son play a bassoon to it!

But if most of his work was unorthodox he was fully conversant with the ordinary theory and practice of zoology and botany. He was out to show that the existing classification was artificial, in the sense that there were no unchangeable lines between species, and indeed that varieties, such as the bulldog or the Manx cat, were species in the making. But as a preliminary to this attack on accepted ideas, he devoted much of eight years to describing and classifying, in six volumes, all the known species of living and fossil barnacles. It is no use attacking a theory till you really understand it, and your attack is most successful if you appreciate its good points from actual experience, and so far as possible preserve them when framing a new theory.

In 1837 Darwin began to make notes on the transmutation of species. By 1844 he had written a sketch of his

views, shown it to colleagues, and asked for it to be published if he died. In 1858, fourteen years later, Alfred Russel Wallace sent Darwin an essay containing many of the same views. Darwin proposed to publish it, and suppress his own book. However, Hooker, who had read Darwin's sketch, insisted that this would be serious loss to science, and finally Wallace's essay was read to the Linnaean Society in 1858 with extracts from Darwin's unpublished book, and from a letter written in 1857. Wallace, who was as magnanimous as Darwin, entirely agreed to this course, and there were none of the petty squabbles about priority which have occasionally disgraced scientists.

In 1859 *The Origin of Species* was published. Its argument falls into two parts. On the one hand evidence is brought forward from the study of fossils, of geographical distribution, of embryology, and of vestigial organs (such as man's ear muscles or the remains of a dog's thumb) that existing animals and plants are descended from very different forms in the past. On the other hand, the theory is put forward that the change has been mainly due to natural selection, or the preservation of favoured races in the struggle for life. For example, within a species some animals have thicker hair than others. Such differences are inherited. The thick-haired animals will survive better in a cold climate, so the species as a whole will tend to have thicker hair. The opposite will happen in a warm climate. Similarly, plants with an inherited tendency to produce flowers whose colour and smell attract bees will be more often fertilized by them than plants with unattractive flowers, and therefore flowers of many species have gradually developed so that they now attract bees.

To-day ninety-nine biologists in a hundred believe in evolution, but a good many doubt whether it can be entirely explained by natural selection, though natural selection is pretty universally admitted to have been one of its causes.

Of course, Darwin's theory was violently attacked by many people. Bishop Wilberforce described it as an 'utterly rotten fabric of guess and speculation', and others used still harsher language. But the majority of biologists, even when critical, could not cope with the incredible mass of facts which Darwin had collected in favour of his theory, and the detail in which he dealt with objections to it, especially in later editions of the book. Hence he carried conviction where earlier evolutionists such as Lamarck had failed to do so. Darwin himself objected to controversy, but he found a number of very vigorous champions, especially T. H. Huxley. He contented himself with bringing forward further evidence in his book on *The Variation of Animals and Plants under Domestication*, and in developing his theories, especially on sexual selection, further in *The Descent of Man*.

It was not till the end of the nineteenth century that the weakest points in the theory of natural selection were discovered. Particularly Darwin's theory of heredity was wrong. The germ-cells do not collect contributions from the various organs of the body, as he believed. And variation is not so continuous as he often suggested. Evolution has not always taken place in small steps. Thus the step from a coloured to a white flower may be taken in a single jump without intermediates. However, these criticisms do not disprove either evolution, or the importance of natural selection. To-day a good many of the other objections to Darwin's views have been met.

Darwin's theories must, I think, be modified in many details, like those of Newton or Dalton, but I, at least, am one of those who regard them as one of the foundations on which biology must be built. As a result of accepting Darwinism, I think most biologists are now materialists, in the sense that they believe that matter existed before mind. Darwin, who was very cautious, did not go so far. He described himself as an agnostic.

As a result of Darwin's work many people have come to believe that our descendants will be much more perfect than ourselves, with less animal characteristics. Others, because they accepted Darwinism, have been much more ready to apply evolutionary theories to society, and to believe that the kind of organization which is best fitted for a people, for example, that of England, changes with time. At one time, feudalism was the best possible system, later on capitalism, while to-day socialism would be better than capitalism. Still others have used Darwinism (mistakenly, I think) to justify war and other brutal kinds of competition. Darwin did not discuss the evolution of societies. But he made it easier for others to do so. In fact, he has had a very unsettling effect on thought, and made it much harder to take a great many current ideas for granted, or to believe a number of doctrines which were thought to be essential to religion.

To sum up, Darwin speculated in the most daring manner. He was extremely cautious in publishing his speculations and extremely honest in weighing the arguments against them. But his mind was dominated by an immense respect for facts, and it is this respect more than any other characteristic which has given him his lasting influence on human thought.

WHAT NEXT IN SCIENCE?

ISOMETIMES read books about the future in which the scientist plays the part of the magician in the old fairy tales. In our grandfathers' time the scientist was a good magician. He was going to make machines to do all our work for us without producing unemployment. Air transport was to usher in an era of universal peace; and so on.

To-day bad magicians are more fashionable. Mr. Wells tells us of new and worse poison gases, Mr. Stapledon of synthetic disease germs, and Mr. Michael Arlen of explosives far more powerful than anything that exists to-day.

Fortunately these stories are as improbable as the others. We know enough about chemistry to be sure that an explosive even twice as powerful as those now existing is impossible. As for synthetic microbes, we can't even make synthetic cane-sugar yet. And chemists have already made a large proportion of the substances which have molecules small enough to enable them to form vapours. In the thirty-two years between 1886, when it was first made, and 1918, nothing worse than mustard gas had been discovered. And I doubt if anything very much worse will ever be made. Mustard gas is bad enough.

Then there are 'death-rays', which may either stop the heart of a man or the ignition of an engine which gets in their path. The first and best of these rays was invented by Mr. H. G. Wells in *The War of the Worlds*. We can

now make rays with every frequency of vibration from less than one cycle per second up to some trillions, and none of them have the properties of a death-ray. However, a death-ray is always worth a paragraph in the press, so we shall go on reading about them for a long time to come. But we need not take them seriously.

So I prefer the good old wizards with their magic wands, and read the *Arabian Nights* and the Welsh *Mabinogion* when I want stories of marvels. The scientist is not the modern equivalent of the wizard for a simple reason. He may discover a new principle, but he cannot apply it to practical purposes without a great deal of help. Science is a social process, like most forms of art. I may discover how to make artificial diamonds, so that every factory girl can have a diamond necklace. But if I do so, it will probably turn out that it pays me best to sell the process for a couple of million pounds to the group which has a monopoly of most of the world's diamond mines. If I don't, I shall probably find myself prevented from making diamonds by an international diamond control board, like those which succeed in making rubber and tin dearer than they need be.

And the subjects on which money is available for research are determined by governments and rich men. The poultry industry is a very important one. The value of the eggs produced in England is greater than that of the wheat. The industry is in a bad way because no one has been able to produce a breed which combines disease resistance with fertility.

I believe this could be done. The science of genetics has done a lot for poultry breeding. About ten million chicks a year are hatched in England from sex-linked crosses, which enable the breeder to determine sex at

hatching. This invention is based on the work of two men, and has certainly brought in a return many hundreds of times what it cost to discover.

To produce a healthy and fertile breed would probably take ten years' work and cost several hundred thousand pounds, perhaps nearly as much as a destroyer, though much less than a battleship. What is more, success cannot be guaranteed. The money might be wasted. But then a single shell might sink the destroyer.

If half a million pounds is wanted for research on metallurgy or oil chemistry, it is soon found, because the metal and oil trades are in the hands of big firms which can put up the money or get a government to do so. But the poultry industry is run by men and women none of whom is rich; so very little is done for them.

The great centre of agricultural research to-day is the Soviet Union, where the little man has found out how to make his voice heard. In the British Empire research on genetics, the science concerned with animal and plant breeding, is being cut down. Our best plant-breeder has had to find a job in Brazil, and one of the two professorships of genetics in England has been abolished. Naturally enough. We are producing more food than can be consumed under capitalism, and it would be silly to find out how to produce still more.

Research on applied science in Britain is mainly concerned with making small improvements in the technique of existing trades. These lead to increased profits and often to increased unemployment. Hardly anything is done to start new industries. This is mainly left to the little man, working with small means, though occasionally a big firm will start a new sideline.

The most likely place for new industries to start is the

Soviet Union, where industry is expanding as it did in England during the nineteenth century. Here are a few which we may expect to start here.

First, rational heating. There is not much coal in the Union, but plenty of water-power to generate electricity. And heating is a far more vital necessity in Russia than in most countries. Now an ordinary fire or an electric radiator is wasteful because heat is produced at an unnecessarily high temperature—red or white heat, whilst it is only needed rather below the temperature of the human body. The heater of the future will not be a fire or a red-hot coil, but a heat pump like that of a refrigerator, with the cold end outside the house, and the hot end inside, worked by electric power. Heat-pumps will probably first be used as part of the Soviet conquest of the Arctic, and later spread to warmer climes.

Simultaneously refrigerators will be developed on a great scale in the tropics, so that however hot the weather may be outside, men may come indoors to a cool room. If British rule in India had been more scientific this kind of refrigeration would be used in that country.

Rational cooking on a factory scale is more likely to start in the Soviet Union than elsewhere. Baking has already been rationalized in some British bakeries. Thousands of loaves are mechanically baked at a time. Cooking will be done in the same way, the meals being served in huge restaurants or delivered at home in cold-proof containers like Thermos flasks. Individual cookery will disappear as individual brewing has done.

In our own country we may expect real progress in medical science. We have already found out how to prevent most diseases caused by bacteria, such as plague, cholera, and diphtheria. An outbreak of typhoid like that

at Croydon is generally only a symptom of 'economy' with the water supply. We can also prevent insect-borne diseases like typhus.

But only in the last ten years have we discovered and sometimes isolated the causes of the air-borne diseases such as influenza, measles, and smallpox. They are too small to see even with a microscope, but they can sometimes be obtained in a pure state by special methods. In the next twenty years we ought to have these diseases under control as we have typhoid and cholera.

Whether we shall do so is another question. German medical science is highly developed, but medicine is progressing backwards in Germany. The death-rate is rising, not falling. The same will happen in Britain if Hitler's highly-placed friends have their way.

Cancer will probably turn out to be a group of diseases like the fevers, each to be prevented by different methods. Some, like the skin cancers of chimney-sweeps and oil-workers, can already be prevented. Most can be cured by early operation, or by radium or X-rays. At any moment someone may discover a better method. But I expect progress will be rather slow, though steady.

So much for applied science. In pure science I expect a period of common sense in physics and astronomy. The great discoveries of the last thirty years led to a lot of wild statements about the expansion of the universe, the annihilation of matter, the free will of atoms, and so on. The facts on which these statements were based will be thoroughly investigated, and woven into a theory, difficult no doubt, but not mysterious; which our grandchildren will learn as we learned our school physics.

Biology will move quickly. The gap between chemistry and life has at last been bridged by the discovery of

disease germs called viruses which behave like ordinary chemicals in some respects, and like living beings in others. We shall gradually discover their properties, and I think we shall find a good deal of the sort of behaviour that we call life in matter which is at present believed to be dead.

We are just beginning to probe the physical basis of mind. We can now record electrical currents produced by the brain so accurately that we can watch the change when a man looks at something or tackles a problem, and can detect certain kinds of madness. We do not yet know where this knowledge will lead us. Perhaps very far indeed.

But all this progress in science is only possible, not certain. Not much research is being done in China or Spain at present. And if the peoples of the world do not control their rulers, the whole world may be like Spain and China in a few years.

PROTOPLASM*

THE progress of science consists in changes of technique and of ideas. The former are the more important, but the latter are the more obvious to onlookers. This is the first of a series of articles* in which it is proposed to examine some of the changes which have taken place, often almost unnoticed, in scientific thought within the last generation. The fourteenth edition of the *Encyclopaedia Britannica* was published ten years ago, and it may be taken as representing the generally accepted thought of its time. We shall therefore quote from it freely, and use passages from it to illustrate the changes which have occurred.

Some concepts which proved very useful in the recent past have been largely superseded. Such are the luminiferous ether, chemical affinity, and the biological value of proteins as food. We know a good deal more than we did about radiation, and the idea of ether as something with properties resembling those of ordinary matter has become ever less helpful or needful to explain radiation. Instead of speaking of the chemical affinity between two substances we use the much more exact and measurable concept of the free energy of their combination. Instead of trying to make a single number represent the biological value of a protein, we give its composition in terms of the various amino-acids into which it can be broken up.

But other concepts have not been so much superseded

* Published in *The Modern Quarterly*. The succeeding article was by Prof. Bernal on 'Matter.'

as left behind. One of these is protoplasm. Dujardin had coined the word 'sarcode' in 1835 for the material of which protozoa, single-celled animals, consist. In 1840 Purkinje invented the word protoplasm for the formative material of animal embryos, and in 1846 von Mohl used it for the gelatinous material in plant cells. This was historically important as a recognition of the essential similarity of the contents of plant and animal cells. Gradually the use of the word spread, and T. H. Huxley defined it as 'the physical basis of life'. This definition is used by the *Encyclopaedia Britannica*.

Why, it might be asked, should we not use a simple and familiar word like flesh? There are several reasons. One is that the flesh or protoplasm forms only a small part of the higher plants. They contain a great deal of wood and fibre, and also sap and stored food materials such as starch and oil. Further we think of flesh as organized into organs and cells, whereas protoplasm is the material of which the cells are largely composed. Finally, such a word as flesh has connotations which are undesirable. In particular religious thinkers have generally regarded life as a temporary union of material flesh and immaterial spirit. It was important, especially if a materialistic theory of life was being put forward, to use a more neutral word.

Fifty years ago physiology consisted of a description of the functions of the various organs, and their correlation. It was known that the processes in living organisms could be regarded as transformations of energy, which was conserved as it is in a machine. But the details of these transformations were almost completely unknown. The activity of an organ such as a contracting muscle, or a secreting gland, was seen to be the sum of

the activities of its constituent cells (a muscle fibre is a highly specialized cell), and the cells were seen to include relatively inert constituents, such as the stiff walls of plant cells, and drops of sap and oil. The active part was the protoplasm, a nearly transparent slimy substance containing particles much smaller than a wavelength of light, and therefore only just visible with a microscope. Even in plant cells the protoplasm was generally moving, often with a streaming motion. The protoplasm was clearly the seat of most of the transformations of matter and energy which took place in living things, and was described as possessing various elementary vital properties such as irritability. It was known that it consisted largely of water, and that its most important solid constituents were proteins (or as they were often termed fifty years ago, albuminous substances). There were smaller amounts of salts, carbohydrates, and oily substances.

To-day one can often read through an entire number of the *Journal of Physiology*, or any similar periodical, without once coming across the word 'protoplasm'. A more frequently used word is 'cytoplasm', denoting the protoplasm of the main part of the cell, as opposed to the nucleus. But no one doubts the reality of protoplasm. The reason for the change in the approach is a technical one. In the nineteenth century the biologists' most important tool was the microscope. Protoplasm represents the substratum of life which is not further analysable by the microscope. It is true that microscopists produced many accounts of the structure of protoplasm. Some said that it was foamy, others fibrous. But these structures were most clearly seen in cells which had been killed and stained, and there was an immense

amount of rather sterile controversy as to how far these structures were present in the living cell, and how far they were artefacts produced at its death.

During the twentieth century new techniques, largely chemical, have given us entirely new possibilities of analysis, and in place of a more or less homogeneous jelly or slime, we regard protoplasm as made up of thousands of different chemical units, each being highly specific. And here at once a criticism is made. The microscopist can observe living cells, though he certainly sees a good deal more after they have been killed and stained. But the biochemist, it is argued, must not merely kill the cells but disintegrate them, and subject them to the most violent treatment before he can isolate any particular substance. How does he know that the substances with which he is dealing are really there in the cell? May not the whole protoplasm of a cell constitute a gigantic super-molecule, of which the biochemist is only studying seriously altered portions?

This criticism has a certain validity, but it has lost much of its force in recent years, particularly as the result of the work of Keilin and Warburg on oxidations within the cell. It had long been known that haemoglobin, the pigment of blood, is purple, but becomes red when it combines with oxygen. However, haemoglobin is a mere carrier of oxygen, which it takes up when passing through the lungs or gills, and gives up again to the organs which use it. In the nineteenth century Macmunn observed colour changes in living cells, particularly muscle, which he attributed to substances like haemoglobin. He did not convince his contemporaries, and it was left to Keilin to confirm and extend his work.

Keilin invented a microspectroscope, with which he could observe a small living object such as a group of yeast cells or a bee's wing muscle. He found that certain dark lines appeared in the absence of oxygen or when the muscle contracted violently. They disappeared when plenty of oxygen was given or the muscle rested. He ascribed them to three substances which he called cytochrome A, B, and C, and managed to prepare cytochrome C in a fairly pure state. It is a pinkish protein to which, as to haemoglobin, iron atoms are attached. Like haemoglobin, it changes colour when it unites with oxygen, but unlike haemoglobin, it is not merely a carrier of oxygen but a catalyst. That is to say, it enables oxygen to oxidize substances which are otherwise resistant to it. So of course does a flame. But catalysts act at ordinary temperatures, and they oxidize substances specifically. That is to say, one catalyst will oxidize glucose (blood-sugar) but not alcohol. Another will oxidize alcohol but not glucose. Whereas flames have very little specificity.

What matters, for our enquiry, is that cytochrome behaves in the protoplasm as it does outside. Its general properties were discovered while it was part of the living system, but naturally more detailed information was gained when it was studied in isolation. These in turn made its function in the living cell clearer. This is not an isolated case. Another* catalyst concerned in respiration was discovered and specified by Warburg by an even more ingenious method. He found that carbon monoxide wholly or partly prevented yeast from taking up oxygen, but that the respiration came back to normal

* Work of Keilin now in the press suggests that it may be responsible for a small part of the 'cytochrome' spectrum.

when a strong light was shone on it. The carbon monoxide combines with a substance concerned in respiration, and the light breaks up the combination. By carefully studying the precise kinds of light which do this, the absorption spectrum of this respiratory enzyme, or rather of its compound with carbon monoxide, was discovered. I showed that it was also present in mammals, insects, and green plants. In these and various other cases it has been possible to apply the laws of physics and chemistry to a constituent of protoplasm in the living cell, without causing the slightest permanent damage to the protoplasm.

The microscopist can only distinguish living from dead cells by their motion or growth. But there is no reason to think that motion is a primitive characteristic of living things. The earliest ones, like some existing bacteria, presumably had a purely chemical relation with their environments. Hence we get nearer to the fundamental characteristics of life by studying its chemistry than its physics.

Now in the nineteenth century chemists studied the food, water, and gases taken in by living things, and their solid, liquid, and gaseous excretions. They also followed the process of digestion, and even the passage of substances in the blood to and from the cells. But an attempt to follow them through the cell was regarded as almost impious and quite impracticable. This would be the case if the protoplasm were a whole which cannot be analysed into parts.

Nevertheless, the twentieth-century biochemists have determined to follow the atoms through their path. Not content to say that yeast makes sugar into alcohol and carbon dioxide, they propose to study the intermediate

stages. Pasteur regarded fermentation as a vital process. Buchner made the important discovery that the juice of dead yeast cells could carry it out, though very inefficiently. Harden separated the juice into two components, neither of which worked alone, though they did so when mixed. Dozens of components are known to-day.

But perhaps the greatest personal force in the study of intermediary metabolism has been Hopkins. Armed with a technical ability which had served to hang several poisoners, he worked out the methods of isolating hitherto unknown substances, and of quantitatively estimating others which were present in very small amounts. His pioneer work with Fletcher showed that lactic acid is formed in a muscle when it works hard, though it is generally used up again very quickly within the muscle-fibres, part being oxidized but most of it put together again as part of a larger molecule. Hopkins' personal contributions to the problem of intermediary metabolism have been relatively small. But the school which he founded, and over a part of which he still presides, has done great things, armed with Hopkins' central idea that the task of the biochemist is to describe all the successive processes which matter undergoes on its way through a living organism.

This is a thoroughly materialistic idea, much more thoroughly so, as we now see, than the idea of protoplasm, which was really a name for our ignorance, only a little less misleading than the expression 'vital force'. We can trace a good many of the stages in some processes, such as the fermentation of sugar by yeast to alcohol and carbon dioxide. One method is to add a substance which combines with an intermediate and prevents it

being used further. For example, sulphite combines with acetaldehyde. Another method is to poison one of the catalysts concerned, so that the reaction stops at a certain stage, and the intermediate accumulates. Thus *Escherichia coli*, a common inhabitant of the human gut (often called *Bacillus coli*) can oxidize lactic acid completely. If poisoned with toluene it oxidizes as much lactic acid as before, but only as far as the first stage, namely, pyruvic acid. The catalyst responsible for the next stage has been inactivated. Yet another method is to study the biochemical genetics of an organism. There are at least twelve distinct recessive varieties of maize which cannot make chlorophyll. This means that at least twelve dominant genes in the normal plant are concerned in the synthesis. Each must be responsible for a different stage in it.

Still more information is gained when we isolate the actual catalysts. Many of these are enzymes, that is to say substances which continue to act when separated from the rest of the cell. About a dozen have been obtained pure, mainly by Northrop and his colleagues in America. All of them are proteins. Hundreds of others have been obtained free from other enzymes concerned in the same process, so that many of their properties can be studied. They are immensely active. A single molecule of catalase can break up half a million molecules of hydrogen peroxide per second, though only in much larger concentrations of peroxide than occur in living cells. But probably the average busy enzyme deals with a hundred or more molecules per second, taking a couple of hydrogen atoms off molecules of succinic acid, coupling phosphoric acid on to sugar molecules, and so on. This means that the tempo of the essential activities

of protoplasm is on a time scale beyond the range of our perception, just as its organization in space is on too small a scale to be visible even with a microscope. Enzymes are also immensely sensitive to their chemical surroundings.

It is becoming more and more plausible that a large fraction of the dry weight of protoplasm consists of enzymes, that is to say, of the machinery for carrying out chemical transformations. Of course in a living cell some of the energy derived from the reactions catalyzed by enzymes is used for synthesis, either of new protoplasm or of products such as the constituents of milk and other secretions which are not merely taken out of the blood. We can only carry out a few of these processes with artificial mixtures of enzymes and the like. Probably the transfer of energy from processes of breakdown to processes of synthesis demands a degree of co-ordination of catalysts which is destroyed when we break the cell up. But we can perform enough synthetic processes with cell products to make it clear that synthesis does not require some special vital force.

We can form no satisfactory estimate of the complexity of the metabolic process. However, I have elsewhere estimated that the average atom in its metabolic path through a cell may come under the influence of about a hundred different catalysts. The total number of catalysts is, however, very much larger than this. That of genes in a cell nucleus is believed to be of the order of ten thousand, each (apart from those of which a pair exists) controlling a different process. These various catalysts determine a network of possible interlacing paths. Thus a carbon atom may enter the human body either as part of a sugar or a fat molecule, and in either

case be deposited in a fat depot under the skin. It may later be used either as a source of energy, or for building lecithin, sphingomyelin, or one of many other waxy substances which form part of the body.

We still lack any at all complete information regarding protoplasmic structure on a level between what we can see with the microscope and what is deduced by organic chemists and X-ray crystallographers regarding the internal structure of molecules. What we have comes from a number of sources. The study of heredity shows how the genes which determine it are arranged in the chromosomes. The detailed study of intermediary metabolism shows, in a few cases, which catalysts work together, presumably in spatial contiguity. A study of permeability tells us something about the arrangement of the cell membrane, and so on. It is precisely at the same level, concerning things between 10^{-4} cm. and 10^{-6} cm. across, that there is an equally serious gap in our knowledge of ordinary matter, but there is no particular reason to expect any very startling novelties at this level. Other similar gaps occur at less than 10^{-13} cm. (interior of nucleus), 10^8 — 10^{11} cm. (interior of earth and planets), and above 10^{25} cm. (limits of our biggest telescopes).

Presumably this region will be investigated largely by physical methods. The main part of the Encyclopaedia article was written by Professor R. W. Chambers, who pushed what may be called the classical physical methods as far as they would go by his improvements in the micro-manipulator by which two quartz points could be manoeuvred with such delicacy as to tear up the nucleus of a living cell, or inject it with a liquid. He was able to show that many apparently solid structures in the cell were far from being so. A quartz fibre could cut through

them and they reformed again. Other structures seemed to be quite genuine solids.

Recent X-ray work by Bernal and others is beginning to show how a liquid can have a structure. One of the heaviest known proteins is the virus causing mosaic disease of tobacco. This protein consists of long molecules or strings of molecules. They are soluble in water, and the solution is not very sticky when dilute. A goldfish swims about in it quite happily. But X-rays show that these long straight molecules are arranged in a regular pattern, with all their axes parallel, and equidistant from their neighbours. The pattern persists in a strong solution. In a dilute solution it is formed on disturbance, but soon breaks up again.

As might be expected, the physical basis of life involves the union of several pairs of opposites. The proteins are large molecules with acid and basic groups, and fairly strong ones at that, some of the acid groups being stronger than those of acetic acid, while many of the basic ones are much stronger than those of ammonia. The molecules as a whole are nearly neutral, though mostly slightly acid. But in solution they have negative charges (extra electrons) where acid groups are ionized, and positive charges where basic groups are ionized. Thus even when dissolved they can arrange themselves in an electric field. Other constituents, such as the sterols, which have no such obvious peculiarities in their chemical structure, form so-called crystalline liquids when melted, thus uniting two very opposite characters.

A fundamental question must now be asked. Granted that protoplasm is the physical basis of life in animals and plants, can there be life without protoplasm, but associated with simpler systems? This depends on what

we mean by 'life'. Some of the proteins show to a greater or less degree, properties which have been regarded as characteristic of living things. Haemoglobin will absorb and give up oxygen. This is hardly respiration though it is a step towards it. Enzymes will carry out chemical processes which no less a biologist than Pasteur regarded as vital. And most striking of all, virus proteins will reproduce themselves when introduced into a cell. It is possible that this reproduction takes advantage of some capacity of the cell for copying, but to my mind it is much more likely that it is due to the building, on a virus molecule, of another similar molecule out of materials pre-existing in the cell. If so the molecular viruses will ultimately be grown in culture media as are many bacteria which were once thought to be obligatory parasites, that is to say, incapable of growth in a lifeless environment. In this case life of a very primitive kind occurs at a sub-protoplasmic level, though indeed the point at which we are to draw the line between living and dead matter has become very arbitrary.

Biologists who take cognizance of the facts so far stated are very often mechanistic, that is to say they expect that it will be possible to give an account of all the main phenomena of life in terms of the properties of cell-constituents. I do not think that this is at all probable. Apart from the weighty philosophical arguments against it, it is out of harmony with what we know of simpler systems, such as molecules and atoms. A molecule exhibits properties which are not found in its atoms, when they are separated. Some of these properties could be deduced from known atomic properties; others could not. That is not to say that they are added from outside. It is rather that the atom in isolation is incapable of

certain kinds of behaviour. In the same way it appears likely that we can learn much, but not all, about the behaviour of proteins in the cell by their study in isolation, just as we learn a good deal about cells by their study in tissue cultures, and about men by their study as isolated individuals in the psychological laboratory or clinic. It would be foolish to reject the findings of individual psychology in a theory of society. But the attempt of certain analysts to construct a theory of social health and disease on the basis of these findings is a kind of mechanism which has not led very far.

Yet just as a man or woman in society is still a man or woman, a protein molecule in a cell is still a protein. It is to the biophysicist armed with such methods as X-ray diffraction that we must look for precise information as to the co-operative properties of proteins which are at the same time the intrinsic properties of protoplasm.

BLOOD ROYAL

A Study of Haemophilia in the Royal Families of Europe

ROYALTY is based on the hereditary principle. The crown of England descends to the eldest son of the late King, or if no such heir exists, according to a not very complicated set of rules. That is an example of legal inheritance. But royalty also illustrates biological inheritance, which follows rules of its own.

Attempts have been made to illustrate the inheritance of various types of human ability by the study of the English royal families. Some of our old medieval kings, such as Henry II and Edward I, were probably well above the average in innate capacity, and it may be that this capacity was inherited. And Queen Elizabeth was probably justified in saying, 'I thank God that I am endued with such qualities that if I were turned out of the realm in my petticoat, I were able to live in any place in Christendom.' However, during the last two centuries it is doubtful whether any of our sovereigns have shown capacities which would have rendered them conspicuous had they been born in a more modest station.

But intellectual and moral capacity is hard enough to assess in an ordinary individual, and still harder in kings and queens, who are not subjected to intelligence tests, or even to ordinary examinations. No attempt to study their heredity from this point of view could lead to results of any scientific value.

However, certain physical characters are clear cut, and

one of these, haemophilia, has played a dramatic part in recent European history. We shall see how Queen Victoria played a minor, but not insignificant, part in bringing about the Russian and Spanish revolutions, and how a rather more materialistic outlook on the part of kings and their advisers might have altered the course of history.

When human blood is shed, it generally begins to clot in a few minutes, the time depending, among other things, on the temperature. The clotting is due to a very complicated chemical process which we need not describe in detail. We are gradually learning to control it. In a case of haemophilia shed blood takes anything from thirty minutes to a day to clot. Hence small cuts may be fatal, and a tooth extraction is a dangerous operation. An ordinary bruise is caused by the breaking of a few blood-vessels, and the subsequent conversion of the blood into green and yellow pigments. In a haemophilic the burst vessels go on bleeding for hours or days, and what would have been a tiny blue mark in an ordinary man becomes a huge dark swelling which persists for weeks. Most haemophilics bleed into their joints and develop a stiffness like that of chronic rheumatism. Although the disease is not painful, apart from such secondary effects as this, it makes ordinary life very difficult, and is generally fatal in the early years of life.

True haemophilia, with one or two very doubtful exceptions, only occurs in males. It is not very rare. At the present moment there are at least thirty-five haemophilics alive in greater London, probably twice as many. If they had a normal expectation of life there would be more than a hundred. So probably well over one English boy baby in 50,000 is born a haemophilic.

Haemophilia is a hereditary disease, though not in the ordinary sense of that word, since it is never (save in one case, where it may have been derived from the mother) handed down, like a crown or an estate, from father to son. On the contrary, although it generally occurs in several males in one family, it is always found that they are related through women.

The laws of descent of haemophilia are simple, but as they depend on rather unfamiliar things, namely, chromosomes and genes, they are at first rather confusing. It is easier to follow them by means of a parable. In a certain savage tribe boys are needed for human sacrifice. They are chosen according to the following plan. Every man has one name, either Abraham or Isaac, which he hands down to all his daughters. Every woman has two names, either Abraham-Abraham, Abraham-Isaac, or very rarely Isaac-Isaac. When a child is born, a priest picks one of these names at random out of a hat, and it is given to the child. If she is a daughter she gets the father's name as well. Boys named Isaac are liable to be sacrificed. So, probably, are girls named Isaac-Isaac.

The facts regarding haemophilia are as follows. Every nucleus of every cell (except some cancer cells and the cells such as spermatozoa destined for reproduction) in the human body contains forty-eight chromosomes, which can be seen with a microscope when the cell divides. A woman has twenty-four pairs, a man twenty-three pairs and two unequal chromosomes called the *X* and the *Y*. A woman has two *X* chromosomes and no *Y*.

This number is conserved by the following process. When an egg is fertilized one chromosome of each pair is ejected in a small granule called the second polar body, so that only twenty-four are left. In the testicles cells

called spermatogonia divide so as to give spermatozoa carrying only twenty-four instead of forty-eight chromosomes. Half receive the X and half the Y . An egg fertilized by a spermatozoön carrying an X gives rise to an embryo with two X chromosomes, and therefore female. One fertilized by a spermatozoön carrying a Y gives rise to a male.

Now the X chromosome includes an ultra-microscopical particle called a gene, which, like the rest of the

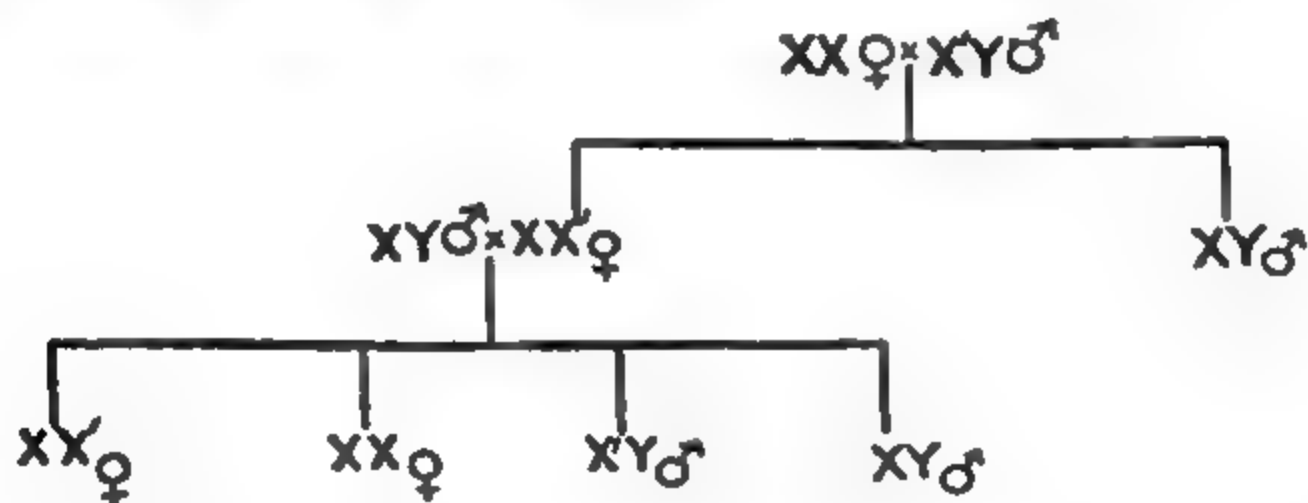


FIG. 1.—The Inheritance of Haemophilia.

chromosome, reproduces itself at each cell division, and which is somehow concerned in making a substance needed for blood coagulation. There are also hundreds of genes concerned in other processes, such as colour vision and tooth growth. The Y chromosome, which is a good deal smaller than the X , carries no genes of these kinds. In a very small proportion of X chromosomes the gene concerned in clotting is replaced by an inactive gene. A man with such an inactive gene is a haemophilic. But as one normal gene will do the work of two, a woman with one active and one inactive gene is generally normal.

The hereditary descent of the inactive gene is the same

as that of the name Isaac in the myth. It can be handed down from a mother to her son or daughter, but by a father to his daughters only. If we represent a normal X chromosome by X , and one carrying the inactive gene for haemophilia by X' , we have the situation shown in Fig. 1. A haemophilic father and a normal mother produce normal children. The sons do not transmit haemophilia to their descendants; but the daughters transmit it to half their sons, on the average; and they transmit the gene to half their daughters. Women of constitution XX' are called heterozygotes. These in turn can transmit it to their descendants, and so on. It is doubtful whether haemophilic women exist. They should theoretically be produced from the union of a haemophilic (X') man and a heterozygous (XX') woman. Half the sons and half the daughters of such a union should, on the average, be haemophilic. But unions of this kind are, of course, excessively rare.

This is the account of haemophilia which is found in textbooks, and it is correct as far as it goes. But it is undialectical. If this were the whole story, haemophilia would soon become extinct, for haemophiles generally die young, and on an average beget only about one-quarter as many children as normal people. However, there is no reason to think that the frequency of haemophilia is diminishing. How then is the supply kept up?

To return to our myth, the priests keep up the supply of sacrificial victims by occasionally altering a name Abraham to Isaac. This is most usually done by surreptitiously converting a Miss Abraham-Abraham into a Miss Abraham-Isaac without her knowledge. So although there had been no history of human sacrifice in her family, she or one of her daughters bears an Isaac.

The process by which a normal gene becomes a haemophilic gene is called mutation. It takes place at the rate of about once in 50,000 human life cycles. That is to say, in each generation about one gene for normal blood-clotting in 50,000 becomes a gene for haemophilia.

As a result of this process the whole human race would become haemophilic in a few million years were it not negated by natural selection, which kills the haemophiles. The same is true for other undesirable genes. Thus the actual frequency of haemophilia represents a balance between the opposing processes of mutation and natural selection.

We do not understand the nature of the process of mutation. If we like to regard the gene as a tiny living unit which reproduces itself, we can say that the reproduction sometimes goes wrong. If we regard it as something copied by the rest of the cell when it divides, we can say that the copying goes wrong.

The process of mutation can be speeded up by heat or by various kinds of radiation, including X-rays and ultra-violet light, provided this latter can reach the sex-cells, which is impossible in man. So it depends on a chemical reaction. But we have no precise information about the kind of reaction, though we can guess.

Haemophilia has occurred in a number of male descendants of the late Queen Victoria; in one son, and in at least three grandsons and six great-grandsons. I have no reason to think that the pedigree here given is complete. Much of my information comes from articles by Fischer.* Fischer, however, thinks that the haemophilia is to be attributed to inbreeding. This is almost certainly incorrect. The vast majority of pedigrees of the disease

* *Zeitschrift für die gesamte Anatomie*, 2, 16, pp. 502, 756 (1932).

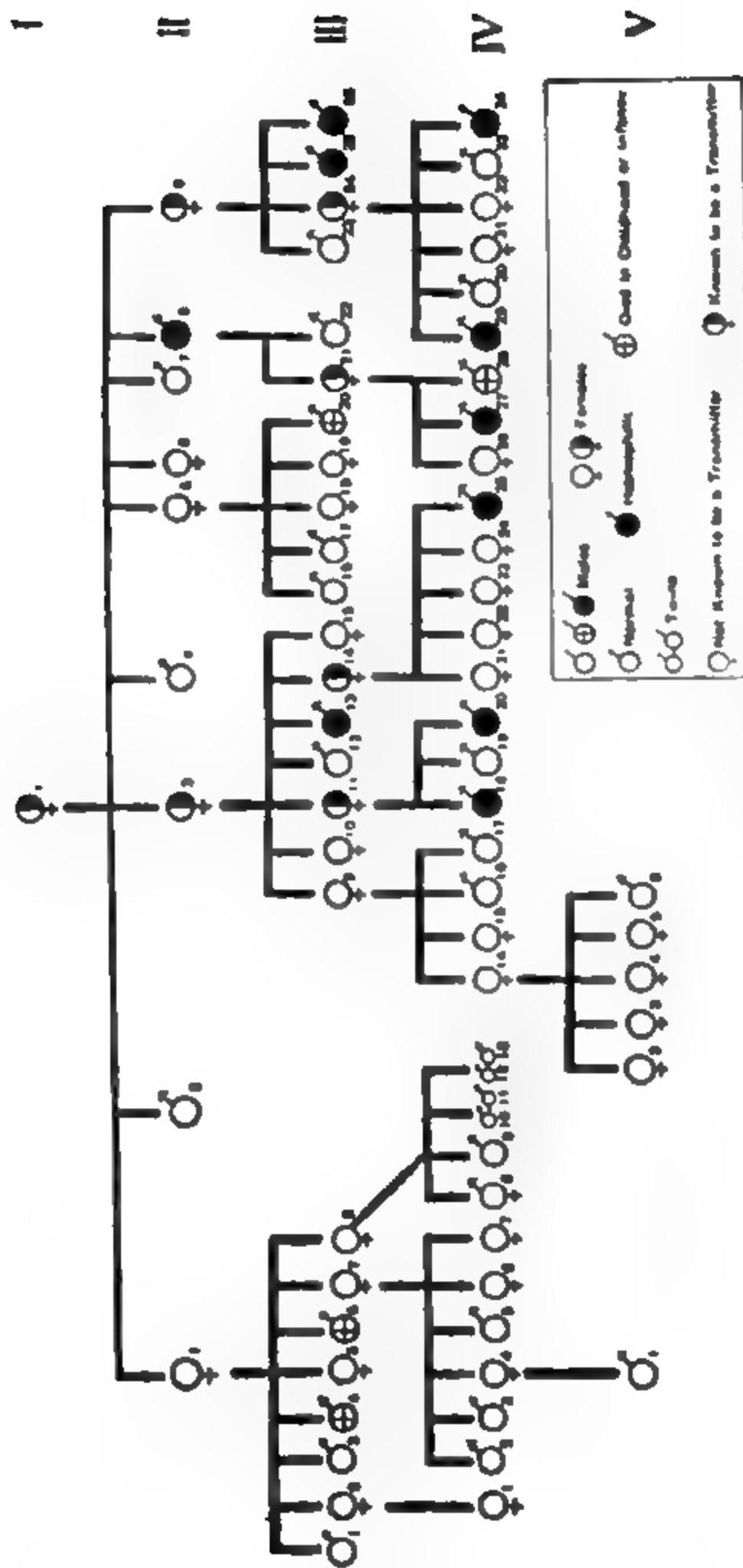


FIG. 2.—Descendants of Queen Victoria.

I (1) Victoria 1819-1901, Queen of England.

II (1) Victoria 1840-1901, x Frederick, later Emperor of Germany. (2) Edward VII 1841-1910, King of England. (3) Alice 1843-1878, x Prince Louis of Hesse. (4) Alfred 1844-1900, Duke of Edinburgh. (5) Helena 1846-1923, x Prince Christian of Schleswig-Holstein. (6) Louise 1848-1919, x Duke of Argyll. (7) Arthur 1850- , Duke of Connaught. (8) Leopold 1853-1884, x Princess Helena of Waldeck. (9) Beatrice 1857- , x Prince Henry of Battenberg.

III (1) William II 1859- , Emperor of Germany. (2) Charlotte 1860-1919, x Duke of Saxe-Meiningen. (3) Henry 1862-1921, Prince of Prussia. (4) Sigismund 1864-1866. (5) Frederica 1866-1929. (6) Waldemar 1868-1879. (7) Sophia 1870-1932, x Constantine, King of Greece. (8) Margaret 1872-1937, x Frederick, Duke of Hesse-Cassel. (9) Victoria 1863-1924, x Prince Louis of Battenberg (Marquess of Milford Haven). (10) Elizabeth 1864-1918, x Grand Duke Sergius of Russia. (11) Irene 1866- , x Prince Henry of Prussia (III (3)). (12) Ernest 1868-1937, Grand Duke of Hesse. (13) Frederick William 1870-1873. (14) Alexandra 1872-1918, x Nicholas II, Tsar of Russia. (15) Mary Victoria 1874-1878. (16) Christian Victor 1867-1900. (17) Albert 1869-1931. (18) Victoria 1870- . (19) Louise 1872- . (20) Harold 1876-1876. (21) Alice 1883- , x Earl of Athlone. (22) Charles Edward 1884- , Duke of Albany. (23) Alexander 1886- , Marquess of Carisbrooke. (24) Victoria Eugenie 1887- , x Alfonso XIII of Spain. (25) Leopold, 1884-1922, Lord Mountbatten. (26) Maurice 1891-1914, Prince of Battenberg.

IV (1) Feodora Maria 1879-1898, x Henry XXX of Reuss. (2) George 1890- , King of Hellenes. (3) Alexander 1893- , King of Hellenes. (4) Helena 1896- , x Carol of Roumania. (5) Paulos 1901- . (6) Irene 1904- . (7) Catharine 1913- . (8) Frederick Wilhelm 1893-1916, Prince of Hesse. (9) Maximilian 1894-1914. (10) Philipp 1896- . (11) Wolfgang 1896- . (12) Richard 1901- . (13) Christoph 1901- . (14) Victoria 1885- , x Prince Andrew of Greece. (15) Louise 1889- , x Crown Prince of Sweden. (16) George 1892- , present Marquess of Milford Haven. (17) Louis 1900- . (18) Waldemar 1889- , Prince of Prussia. (19) Sigismund 1896-1927. (20) Heinrich 1900-1904. (21) Olga 1895-1918, Grand Duchess. (22) Tatiana 1897-1918, Grand Duchess. (23) Marie 1899-1918, Grand Duchess. (24) Anastasia 1901-1918, Grand Duchess. (25) Alexis 1904-1918, Tsarevitch. (26) May 1906- , x Captain Henry Abel-Smith. (27) Rupert 1907-1928. (28) Maurice 1910-1910. (29) Alfonso 1907- , Prince of Asturias, now Count of Covadonga. (30) Jaime 1908- . (31) Beatrice 1909- . (32) Maria 1911- . (33) Juan 1913- . (34) Gonzalo 1914- .

V (1) Michael 1921- , Prince of Alba-Iulia. (2) Margaret 1905- , x Godfrey of Hohenlohe-Langenburg. (3) Theodora 1906- , x Margrave of Baden. (4) Cecilia 1911-1937, x Grand Duke of Hesse. (5) Sophia 1914- , x Christopher of Hesse. (6) Philippas 1921- , Prince of Greece.

show no inbreeding. Inbreeding may be responsible for several other physical and mental defects which occur in certain royal families, but it is not responsible for this one.

It is quite likely that several other males have been haemophilic. 'The fierce light which beats about a throne' is a spotlight artificially manipulated rather than the normal light of day, and does not illuminate all the defects of royalty. The evidence given by Fischer and others is in most cases clear. But that concerning three princes is not stated.

The pedigree is given in Fig. 2. It only includes descendants of Queen Victoria through females or through a male haemophilic. For this reason I have omitted the present British royal house, the descendants of King Edward VII. As he was not a haemophilic, and none of his descendants have married into a haemophilic family, the Windsor dynasty has no haemophilic genes either on the surface, so to say, or below it, and there is no more likelihood of a haemophilic appearing among them than in any normal family, even were they to begin inbreeding once more in a later generation. Rumours to the contrary, which are quite unfounded, are due partly to suppression of the real facts, partly to ignorance of genetics.

Details of the haemophilics are as follows, mainly after Fischer.

II 8. Leopold, Duke of Albany. Was an invalid from birth. Described as having 'a skin as thin as tissue paper'. This is probably incorrect. But a scratch which a normal child would not have noticed must have bled for days, thus giving an impression of thinness. His illness included an intestinal haemorrhage in 1875 (see letters and diaries of Queen Victoria).

III 13. Prince Frederick William of Hesse. When two years old he bled for three days from a cut on his ear. A little later he died as the result of a fall from a window.

III 25. Prince Leopold of Battenberg. No details given by Fischer.

III 26. Prince Maurice of Battenberg. No details given by Fischer.

Prince Maurice died of wounds whilst fighting in the British army in 1914. If he was a haemophilic this argues great courage on his part, as he must have known that a trivial wound might be fatal.*

IV 18. Prince Waldemar of Prussia. No details given by Fischer.

IV 20. Prince Henry of Prussia. Died after a fall, apparently from meningeal haemorrhage.

IV 25. Tsarevitch Alexis of Russia. He is well known to have been a haemophilic.

IV 27. Viscount Trematon. Died of uncontrollable bleeding after a motor accident.

IV 29. Alfonso, formerly Prince of Asturias. Now Count of Covadonga. His haemophilia has been a well-known newspaper feature since he went to America.†

IV 34. Infante Gonzalo. Died of uncontrollable bleeding after a motor accident.

A few remarks on the pedigree may now be made. A woman is certainly heterozygous for haemophilia if her father was a haemophilic. The same is true if she belongs to a haemophilic family and bears a haemophilic son. In a normal family such a son may possibly be due to

* Since this article was written a communication from his former batman, now in Canada, has confirmed both his haemophilia and his courage.

† Since died of haemophilia.

mutation. If a woman in a haemophilic family produces no sons, we cannot tell whether she was heterozygous. Several examples of such women may be found in Fig. 2. If a woman is a potential heterozygote or carrier (e.g. because she had a haemophilic brother, which proves that her mother was a carrier), and has borne no haemophilic sons, we cannot say that she was not heterozygous. Thus II 5 (Princess Helena) bore three sons, of whom two at least do not seem to have been or to be haemophilic, and the third may not have been. The probability that a heterozygous woman should bear three normal sons is one in eight. Thus Princess Helena may have been heterozygous, even if all her sons were normal.

A further complication arises from the deaths in infancy or childhood of a number of boys, marked with the sign \oplus . Out of twelve sons of Queen Victoria's daughters, no less than four died before the age of 12 years. Only one of their twelve sisters did so. It is quite possible that III 13 (Prince Frederick William of Prussia) was not the only haemophilic among them. III 4 (Prince Sigismund of Prussia) may have died of meningitis, as officially stated, or he may have died of meningeal bleeding as his cousin III 13 probably did. Further, IV 28, who only lived for five months, may have been haemophilic, and it is possible that IV 30 (Infante Jaime) is also haemophilic.

We must now turn to the origin of the disease. The relevant parts of Queen Victoria's pedigree are shown in Fig. 3. Her half-brother, her three maternal uncles, and her maternal grandfather all lived long enough to marry and beget children. We may take it that they were not haemophiles, for about 1800 bleeding was so extensively

carried out by the medical profession that haemophilics would not have lived for many years. Nor have I been able to trace haemophilia either among her mother's sisters's sons or in the house of Reuss from which her grandmother was derived.

Further research by others may well discover such a case. But on the existing information it is unlikely that the gene for haemophilia should have been handed down

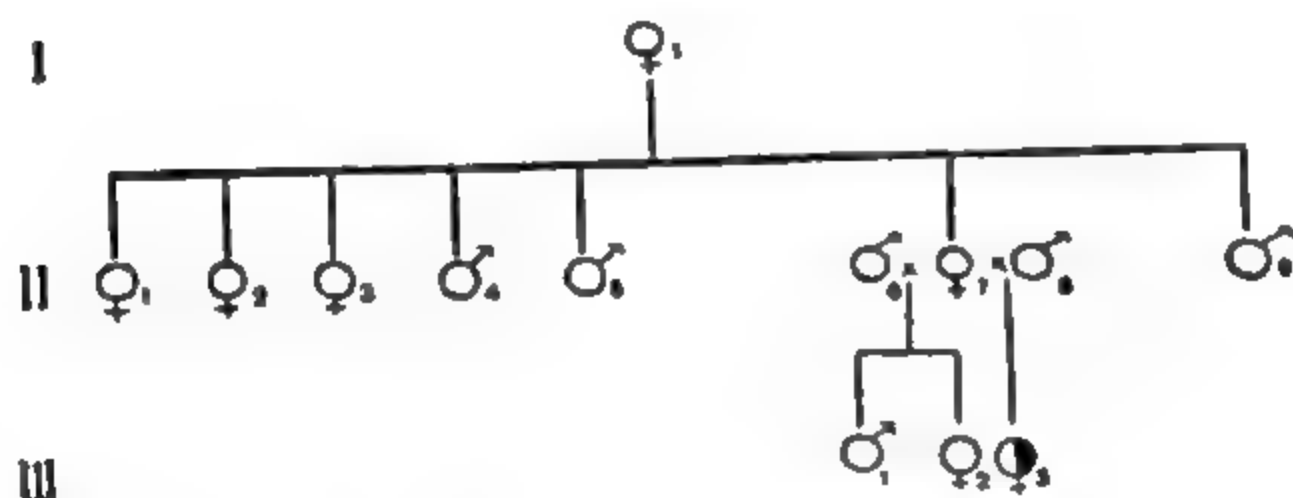


FIG. 3.—Ancestry of Queen Victoria.

I (1) Augusta Princess of Reuss, 1757, x Frederick, Duke of Saxe-Coburg-Saalfeld.

II (1) Sophia 1778. (2) Antoinette 1779. (3) Henrietta 1781. (4) Ernest, Duke of Saxe-Coburg-Gotha, 1784. (5) Ferdinand 1785. (6) Emich, Prince of Leiningen. (7) Victoria 1786. (8) Edward, Duke of Kent, 1799. (9) Leopold, King of the Belgians, 1790.

III (1) Charles, Prince of Leiningen, 1804. (2) Anne 1807. (3) Victoria, 1819-1901, Queen of England.

from Augusta of Reuss to Victoria of England without appearing in any of the males who could have borne it.

The gene must have originated by mutation, and the most probable place and time where the mutation may have occurred was in the nucleus of a cell in one of the testicles of Edward, Duke of Kent, in the year 1818.

The event in question could not have been observed with the most powerful microscopes. It initially affected a single gene, that is to say a particle much less than a thousandth of a millimetre in diameter.

But it had an appreciable effect on world history. As Marx wrote to Kugelmann in 1871,

History would be . . . of a very mystical nature if 'accidents' played no part. These accidents themselves fall naturally into the general course of development and are compensated again by other accidents.

A mutation is strictly an accident. It is an uncontrollable event which occasionally interferes with the normal process of heredity. What is more, it is an event which occurs in a single molecule as the result of a sudden high concentration of energy produced by random shocks of molecules or electrons. If the uncertainty principle is correct, it is by its very nature incapable of control by man.

This accident was definitely detrimental to the cause of monarchy, and to the cause of capitalism, which uses monarchs as its agents. The Tsarevitch Alexis, son of Nicholas, the last Tsar of all the Russias, was a haemophilic. The monk Rasputin obtained a hold over his parents through his alleged ability to control the boy's bleeding. This may have been spurious, but it is possible that by hypnosis or a similar method he could cause contraction of small arteries. These are under nervous regulation, and although not normally controlled by the will, they can be caused to contract in a hypnotized subject.

Whether or not Rasputin was able to influence the Tsarevitch, he certainly influenced his parents. And his

murder by a group of aristocrats did something to break up the unity of the ruling class, and thus to facilitate the Revolution of March, 1917. Further, the fact that Alexis was a haemophilic must have militated against the proposal that he should succeed his father when the latter abdicated.

In Spain, too, the heir-apparent was a haemophilic at the time of the Revolution which dethroned his father Alfonso XIII in 1931, and the second son is said to be an invalid. These facts unquestionably made it harder for moderate monarchists to propose the replacement of the reigning sovereign by the heir-apparent, the solution which commended itself to the British ruling class in 1936.

And both in Russia and Spain it seems likely that the people in general regarded the existence of haemophilia in the royal family as a sign of divine displeasure. We need not adopt their terminology, but we shall find reason to believe that their judgment was substantially correct.

The appearance of haemophilia in the British royal family in the nineteenth century was an accident, like Blanqui's illness at the time of the Paris Commune, and many other details of individual human biology which have affected history. But its appearance in the royal families of Russia and Spain was not an accident at all.

The laws governing the inheritance of haemophilia were largely discovered by John C. Otto, a physician of Philadelphia, in 1803. He stated that 'males only are affected and all are not liable to it. Though females are free they are capable of transmitting it to their children.' In 1805 Dr. John Hay, of Reading, Mass., confirmed Otto's views with further examples.

In 1820 Professor Nasse, of Bonn, confirmed their results, and during the twentieth century the modern theory, which I have given above, was developed. Thus by 1853, when Prince Leopold, Duke of Albany, the first of the royal bleeders, was born, the heredity of the disease had been understood for half a century. It was known that the mother of one bleeder might produce more, and that his sisters might have haemophilic sons. Nevertheless, all Queen Victoria's daughters married, though one (Princess Louise, Duchess of Argyll) was childless. And of the four who had children, two, and possibly three, had haemophilic sons.

It was thus clear that Prince Leopold was not an isolated case. Considering the expense and ceremony which are associated with royal marriages, and the importance attached to the personality of kings, it might at first sight have been thought that some care would be taken in choosing the mothers of future royalty.

Actually, however, importance is attached to their ancestry from the legal, but not from the biological point of view. Presumably Nicholas and Alfonso knew that their brides had haemophilic brothers, but their education had been of such a character that this meant nothing to them. They or their advisors may have consulted physicians. We do not know, and are not likely to know, whether in either case the court doctor advised against the marriage. And I doubt whether a distinguished medical man outside court circles who has wished to warn Nicholas or Alfonso of the dangerous character of his intended marriage would have been able to do so, either personally or in the columns of the Press. Kings are carefully shielded against unpleasant facts, and must suffer in consequence.

This has not always been the case. But in the nineteenth century they became more and more tools of the bourgeoisie and isolated from realities in an atmosphere of unctuous piety mitigated by covert sensuality. The straightforward and materialistic facts about the inheritance of haemophilia were discovered by contemporaries and neighbours of Benjamin Franklin. They were not the sort of things which could be discussed in a nineteenth-century court.

The haemophilia of the Tsarevitch and the Prince of Asturias were symptoms of the divorce between royalty and reality. The court of Queen Victoria was very different from that of Henry VIII, where the spectators in the gallery jumped down and tore the cloth-of-gold off their king at the conclusion of a dance, or that of Charles II, the first patron of the Royal Society, who is said to have dissected a foetus dropped by a court lady during a ball.

One further point may be made. Under the bill to legalize eugenical sterilization which it is intended shortly to bring before Parliament,* it is proposed that persons who are deemed likely to transmit a grave physical defect to later generations be sterilized, though only with their own consent. A draft American law would make sterilization compulsory for a group of persons more precisely defined, who would have included Queen Victoria and all her daughters.

I find it difficult to suppose that, had the first of these laws been in force, the court physician would have proposed, shortly after the birth of Prince Leopold, that Queen Victoria herself, and the future Empress of Germany and Princesses of Hesse, Schleswig-Holstein, and

* *Eugenics Review*, July, 1935.

Battenberg, with the future Duchess of Argyll, should all be sterilized.

Still less do I believe that, had a law for compulsory sterilization been in force, the Medical Officer of Health for Westminster would have called round with a warrant for the sterilization of the princesses, who, of course, are subjects, and must therefore obey Acts of Parliament.

I am led to this belief by the following observation. Imbeciles are defined under English law as

"persons in whose case there exists from birth or from an early age mental defectiveness not amounting to idiocy, yet so pronounced that they are incapable of managing their own affairs, or, in the case of children, of being taught to do so."

A study of the proceedings of the bankruptcy courts shows that a considerable number of the nobility are incapable of managing their own affairs. They are not, however, segregated as imbeciles on that ground. It may be that the affairs of dukes are harder to manage than those of dustmen. If so a higher standard should be set when breeding dukes.

Ruling classes perish through incompetence rather than injustice. The story of Fig. 2 is the record of one little piece of incompetence in our ruling classes. In the Middle Ages care was taken, in terms of prevailing biological theories, to obtain kings of the desired sort. It was an act of High Treason to seduce the wet-nurse to the heir-apparent of England,* thus corrupting the blood royal. The blood royal has actually been corrupted by snobbery, which puts 'high' birth before health.

* I have been unable to verify the existence of this remarkable crime, but believe it to be a product of the imagination of a medieval jurist, rather than of my own.

There is a great deal to be said for eugenics. But as I have pointed out elsewhere,* it suffers from the grave defect that it has been used, and is being used, as an instrument of oppression in the class struggle. I trust that I have shown that it is not only among the 'lower' classes that eugenic principles might be applied.

• *Heredity and Politics* (Allen and Unwin, 1938).

HUMAN BIOLOGY AND POLITICS *

SIR NORMAN LOCKYER, whose name is commemorated by this lecture, was fortunate in certain respects. His work on the chemistry and physics of the sun, revolutionary as it was from the point of view of pure science, did not bring him into conflict with established interests either in religion or politics. This was, in a way, accidental. The scriptures might well have contained misleading passages concerning the composition of the sun, as they do about its motion. And had the persons with a vested interest in nineteenth-century methods of illumination been sufficiently far-sighted, they would have realized that a study of line spectra was likely to render obsolete all lighting methods based on the emission of a continuous spectrum, and have done their best to discourage this study.

The student of human biology can hardly hope for such immunity from worldly contacts. He may discover facts which go far to disprove the theories by which current politics, economics, hygiene, religion, and morality are supported. And he will not even have the satisfaction of wholeheartedly taking sides in a controversy. At one moment he may find himself attacking a religious dogma, at the next supporting the Pope against people who regard themselves as progressive. If he defends the medical profession against some of its opponents, he will be bound to admit that the Pharmacopeia embodies many practices which have absolutely no scientific found-

* A lecture delivered in London.

ation. In most human controversies truth resembles the Mexican god Yaotl, familiar to readers of Cabell's *The Silver Stallion*. It is the enemy on both sides.

I shall naturally be dealing with aspects of human biology which are controversial to-day. It is worth remembering that a good deal which is common sense in Britain to-day was once a novel and revolutionary hypothesis, and still is so in some primitive communities. It is said that certain peoples recognize no relation between sexual intercourse and the birth of children, but regard conception as solely due to the entry of a spirit into the mother. Others refuse to admit any causes of death except human agency, ascribing what we call natural death to sorcery. In each case we now accept the materialistic explanation without question. (Perhaps I should except 'Christian Scientists', who attribute disease to error on the part of the diseased or malicious animal magnetism employed by others!) Nevertheless, the fact that we rarely give children a perfectly straightforward account either of birth or death shows that very deep psychological resistances to clear thinking on either subject still exist in our society. Neither I nor my hearers can hope to avoid emotional prejudices when we take up these subjects.

These fundamental facts of human biology are as much part of the common stock of ideas on which we all act as are certain fundamental facts of chemistry or physics. For example, everyone knows that the rapid oxidation of cellulose is an autocatalytic process, in other words, that one can light one piece of wood from another, a very fundamental and revolutionary discovery in its time. Other chemical and physical facts, not so generally known, are applied in industry, others again await

application. What are the facts of human biology analogous to these two latter classes?

The most important group of data applied by specialists are those which constitute the medical sciences. Those which are not applied in medicine are, to a very large extent, not applied at all. Either they have no obvious application, or they form the basis of arts such as Eugenics, which, like inter-planetary navigation, are not yet practised, at any rate in this country, even if their principles are partly understood.

Before I come to my main theme, I must crave your indulgence while I say a few words about the medical profession. The application of science to other branches of life has led to increase in organization. Some of these organizations are capitalistic like the railways or the great industrial combines, others socialistic like the Post Office or Woolwich Arsenal. But though we do not go to an individual artisan for our car or to an individual water-carrier for our water, we still go to an individual doctor for our healing. The largest organizations for medical and surgical treatment are the voluntary hospitals, which are neither capitalistic nor in this country socialistic, but survivals or imitations of medieval foundations. A few large clinics and nursing-homes are run as business concerns.

The result is most unfortunate. The patient consults a doctor who is supposed to understand the whole gamut of human ailments, from broken bones to madness. If poor, he or she may ultimately be admitted to a hospital, but too often after a considerable delay. The middle-class patient is treated in his own home or in a nursing-home, where conditions are generally far worse than in a hospital. There are generally fewer specialists available,

less adequate apparatus and laboratory facilities, and less constant attendance by nurses. Only the very rich secure as satisfactory treatment as the hospital patient. I speak from experience of both. I have been in a really good nursing-home. I have also been in one where the conditions were inferior to those of the better hospitals in Mesopotamia in 1917.

The system is obviously unsatisfactory. Though I should prefer to see a State medical service, I am sure that the middle-class patient would be very much better off with a capitalist type of medical organization than at present. He could go to an institution where he would find a team of competent specialists including a radiologist and a bacteriologist, and would very probably be able to avoid the very heavy occasional costs of illness by paying a fixed annual fee.

As medicine becomes more and more a matter of prevention as well as cure, the defects of the existing system show up more clearly. The preventive and prophylactic side of medicine is represented by the medical officers of health, the school medical officers, and a few voluntary institutions such as the Peckham health centre, which are models of what should be; but under a system of individual medical attendance adequate disease prevention is almost impossible, if only because it is far harder to detect latent disease in an apparently healthy person, than to determine the nature of a disease already existing.

If the existing knowledge of human biology and that which is likely to come into existence in the near future were adequately applied, there would, as we shall see, be an enormous demand for experts. It is a very serious question whether they should be members of the medical profession. Again, it has been suggested that sufferers

from certain incurable diseases should be killed, that persons with hereditary defects should be sterilized, and that abortion should be permitted in certain cases where the mother's life is not in danger. If any of these practices are legalized I sincerely hope that they will not be entrusted to the medical profession. The relation of the physician to his patient should always be that of a healer, never of a killer, and the whole psychology of that relation would be profoundly altered for the worse if this ever ceased to be the case. This fact was realized by the wise man or men who framed the Hippocratic Oath. If public opinion demands the application of medical technique to such ends as I have suggested, the profession will be well advised to surrender some of their rather jealous guardianship of this technique, rather than extend their functions unduly.

For the same reason I believe that it is desirable that the experts who in the future will be concerned, as I believe they will, with the enforcement of standards of diet, housing, reproduction, and so on, should not be medical men, though they will have to learn much of the science which is now taught only to the medical profession. The alternative would be an hypertrophy of the medical profession such as occurred in the Middle Ages when the church concerned itself not only with spiritual affairs but with government, education, and handicraft. Such an hypertrophy could only end in disaster. An expert on human biology need not be a doctor, and in many cases should not be, any more than every clerk should be in holy orders.

For as soon as human biology ceases to deal with the individual, it becomes inevitably mixed up with politics. In this lecture I propose to examine some of these reper-

cussions. I shall deal chiefly with the questions connected with human reproduction, the questions of the quantity and quality of our future population. Here I have the advantage that the subject has already been treated by Dean Inge, who preceded me in this lecturership. It is always interesting to study the reactions of an intelligent outsider to scientific thought. But such an outsider is apt to label as scientific, ideas which have but a meagre claim to that title.

Let us begin with the question of numbers. Dean Inge believes that a happy and healthy England would be more sparsely populated than at present, by a population largely engaged in agriculture. This is only true if it is impossible to keep an industrial population healthy and happy. It will be time to conclude that this is impossible when the attempt has been made on scientific lines, and not till then. An urban population living in unplanned houses, and eating an unplanned diet, is bound to be less healthy than a rural population. An urban population which was adequately fed, and had opportunities for sport and country travel might be healthy enough. When I climb Snowdon, as I have done at least once, without meeting anyone else, I cannot resist the conclusion that our population is ill distributed rather than too large.

Whether I am right or not, it is certain that our population is going to diminish very greatly in the near future. This prediction is based on the statistical methods introduced by Dublin and Lotka in the United States, and by Kuczynski in Europe. Their work has recently been popularized by Charles in *The Twilight of Parenthood*. If we have a table of deaths at different ages and children born by mothers of different ages, we can readily make the following calculation. If 1000 girl babies are subject

to these death-rates and birth-rates, how many daughters will they produce in the course of their lives? In England to-day this figure is about 750. The figure 0.75 is called the net reproduction rate. The population is still increasing because there are a large number of women of child-bearing age, but it will begin to fall within the next ten years. Wherever the net reproduction rate is less than 1, the population is bound to fall. In our own country at least, no improvements in hygiene can possibly counteract the tendency. If we take 1000 girl babies and suppose that none of them dies before the age of 50, while their fertility in each year is unchanged, we get a figure called the gross reproduction rate. This is, of course, higher than the net rate, but in England and Wales it fell below unity in 1927.

Similar figures are available for a number of other countries. The net rate is below unity throughout North-Western Europe, including France and Germany.* It is near unity in central Europe, and rapidly dropping towards that figure in Italy and the Balkans. For example, the net reproduction rate in Bulgaria fell from 1.9 in 1903 to 1.3 in 1929, and is probably now very little above unity. In the United States it probably fell below unity in 1927. In the British self-governing dominions it is still slightly above unity, but approaching that figure. The position in the U.S.S.R. and Japan is entirely different. In 1926-7 the net reproduction rate of the former country was 1.7; that of Japan is also very high, though really adequate figures are lacking. It is of course probable that in both these countries industrialization will ultimately lower fertility, but there are as yet no clear signs of this tendency.

* Hitler raised it temporarily.

The political consequences of these facts are interesting. Dean Inge disapproves strongly of Communism, and thinks that England should play an important part in combating it. But he approves of a trend in population which is rapidly rendering England, and all other capitalist countries save Japan, less and less capable of effective action against the Soviet Union, should such action be desired by those who regard our civilization as superior to that of the Soviets.

Though I do not share all the Dean's views on international politics, I think that a great diminution of our population, while that of other countries is increasing, would intensify the present instability of the international equilibrium. If the population of Australia does not increase much more, while that of Japan does so, it will become increasingly difficult either morally or physically to resist the Japanese claim to immigrate into that continent. I think that it will be generally agreed that, even if a slight diminution in our population is desirable, the catastrophic fall which will occur if the fertility of Englishwomen is still further diminished, is undesirable. I shall consider later what steps should be taken to check this fall.

We next come to the question of quality of population, by which I mean innate quality. Dean Inge makes the surprising remark that 'any progress which is not based on an intrinsic advance in human intelligence is very precarious'. Of course all progress is precarious, but I have yet to come across any evidence whatsoever that there has been any advance in the intrinsic factors making for intelligence in Europeans during the last 50,000 years. We have no reason to suppose that a hundred babies gathered from Solutrean caves and trans-

ported by a time machine into the year 1934 would grow up, on the whole, stupider than the rest of us. Progress as far as I can see has been due to the substitution of one type of production by another, and in so far as the new social organization has been stable, the progress has been of a fairly permanent character. Progress and evolution are different processes with different time scales. We are surprised if we can detect evolutionary change in a section of the geological record covering as little as 20,000 years. But the whole of human progress since the old Stone Age is comprised in less than this period. It is no doubt desirable that man should evolve in certain directions, but such evolution is a quite different thing from social progress. It may be that there is a limit to the social progress possible without further evolution, but before such a conclusion is proved a good many experiments will have to be made; and the statement that the limit of progress has now been reached need not be taken seriously except as an expression of conservatism in the speaker.

As regards innate human quality three ideals are held up. Certain relatively rare types should be eliminated, certain classes within a given community should be encouraged to perpetuate themselves, while others should not. And certain races should be prevented from immigrating into given areas or expelled from them. Curiously enough, eugenic organizations rarely include a demand for peace in their programmes, in spite of the fact that modern war leads to the destruction of the fittest members of both sides engaged in it.

Let us first consider the undesirable innate characters which we want to eliminate. Many of them are due to the

substitution of one gene for another. That is to say, they are inherited in accordance with Mendel's laws. For example, 'lobster claw', a rare condition in which the hand and foot are reduced to a single pair of digits, is handed down by affected persons to about half their offspring, and never skips a generation. It is due to the substitution of an abnormal gene for one of the genes concerned in limb development. Affected persons have one normal and one abnormal gene of this pair, and hand down each to half their progeny. A gene like this which produces effects when heterozygous, i.e. associated with a normal allelomorph, is said to be dominant. If all affected persons were prevented from breeding, the condition would be wiped out in a generation, save for the very rare cases, probably less than one in a hundred million, where the abnormal gene arises anew by the process called mutation. In this case we should be sacrificing one normal child for each abnormal whose birth was prevented.

Some other dominant characters would not be so easily extinguished. Thus one cause of congenital mental defect is epiloia, or tuberous sclerosis. This is a dominant, but is rarely handed down for more than two generations, as it causes early death as well as mental defect. Unfortunately this adverse natural selection is balanced by mutation. Penrose * showed that at least 20 per cent of a series of cases arose in this way. So here sterilization would only reduce the incidence by about 80 per cent even if every case were diagnosed, which is unlikely, and does not always cause mental defect. In only 22 per cent of Penrose's cases had the disease been actually diagnosed

* Penrose, L. S. *The Influence of Heredity on Disease*. London, 1934.

in a parent, so probably sterilization would only give a reduction of this order.

Again, Huntington's chorea is a dominant. This terrible disease begins with involuntary muscular movements, which are the first symptoms of a nervous disease culminating in madness and death. The average age of onset is about 35. By this age most people have already begotten the majority of their children. The sterilization of subjects of this disease under the recent German law, even if carried out very thoroughly, will therefore not abolish it within a measurable time, though it will slightly diminish its incidence. It could only be wiped out by preventing all children of affected persons from breeding, a sacrifice of 3 normal children for each abnormal.

Another group of diseases are sex-linked recessives such as haemophilia. This condition is due to a gene carried in the X chromosome, of which women possess two and men only one. A woman carrying one gene for haemophilia is normal but transmits the condition to half her sons. An affected male does not transmit it to his daughters, but it reappears in half their sons. However, it is so fatal that haemophilics rarely marry, and Bulloch and Fildes* even doubted whether it was ever transmitted by a male, though I think the evidence for this is very strong. Haemophilics certainly should not beget children, though as they rarely do so, a prohibition would have little eugenic value. They could not be sterilized by operation, as this would often be fatal. X-rays might be used. The only measure which would appreciably diminish the frequency of haemophilia would be the prevention of further child-bearing by healthy women who have had a haemophilic son, and by the sisters of

* Bulloch and Fildes in *Treasury of Human Inheritance*. Vol. 1.

haemophilics. The sterilization of mothers would sacrifice three normal children for each abnormal, that of sisters seven normals for each abnormal. Such measures would perhaps be justifiable were the population increasing rapidly. I doubt if they would be so at present.

Finally, we come to recessive abnormalities. These include many forms of blindness and deafness, and at least two forms of idiocy. The case of juvenile amaurotic idiocy is typical. This is due to the compresence in an idiot of two abnormal recessive genes, one contributed by each of two normal but heterozygous parents. When such parents marry, on the average one-quarter of their children are affected. No case is recorded where an amaurotic idiot has lived long enough to have children. If two grandchildren of the same heterozygous carrier marry, the chance that both will be heterozygous is one-sixteenth, whereas the chance that two unrelated persons will carry it is (in the population of Sweden) about one in 15,000. Hence it is not surprising that the condition is very much more frequent among the children of cousins than in the general population. Sjögren * found that 15 per cent of the Swedish cases were the children of first cousins, and a further 10 per cent of other relatives. Similarly Usher † found that 24 of 79 English cases of retinitis pigmentosa, a disease which causes about 4 per cent of all blindness, were the offspring of first cousins, and 4 more of first cousins once removed.

It would be useless in such cases to sterilize the affected. Very often they do not breed, and when they do their children are generally normal. There is also no

* Sjögren, T. *Hereditas*. Vol. xiv. p. 197, 1931.

† Usher, vide Bell in *Treasury of Human Inheritance*. Vol. 2.

prospect of eliminating the recessive genes. Nearly 1 per cent of Swedes are heterozygous for amaurotic idiocy, and probably most normal people carry some deleterious recessive gene.

At present only two eugenic measures are available. One is to discourage the marriage of cousins. The only body that does this is the Roman Catholic church, which is, however, hostile to other forms of eugenics. The other would be to allow or enforce the sterilization of one partner in a marriage which had produced a recessive, or to sanction or even compel the dissolution of such marriages.

Deaf mutes present a special problem. Deaf mutism may be congenital or due to infantile ear disease. Congenital deaf mutism is largely due to recessive genes, as appears from the fact that, in different populations, from 21 per cent to 40 per cent of congenital deaf mutes are the progeny of consanguineous marriages. But deaf mutes very frequently marry. Were all deaf mutism due to a single recessive gene the progeny of two congenital deaf mutes would always resemble their parents. Actually several genes are concerned. So most marriages of congenital deaf mutes give normal children. Nevertheless, Dahlberg * finds that 29 per cent of the children of two congenital deaf mutes are deaf mutes. I think there is a good case for sterilizing the husband in such a case, more especially as it is clear that normal children brought up by two mute parents must be considerably handicapped.

The scope of negative eugenics, as applied to physical defects, seems then to be severely limited. The possible methods include not only prevention of procreation by

* Dahlberg (1930). *Zeit. Konstitutionslehre* 15, p. 492.

affected persons, but also by their relatives, besides the discouragement of inbreeding and the dissolution of certain marriages. Actually the prospects are far brighter than this. We know so little of human genetics that only such rough-and-ready methods are at present available. But if we possessed the same knowledge of human genetics as we do of the genetics of *Drosophila* or maize, we should be able to say, with very high probability, that such and such children of a sufferer from Huntington's chorea has received the gene for it, and should not marry; that some of the brothers of an amaurotic idiot carried the gene for that disease, and others did not. Possibly we could detect the gene for haemophilia in heterozygous women, and so on.

This sort of thing is possible in *Drosophila* because harmful genes, for example, for short wings or defective eyes, are carried in the same chromosome with harmless ones such as those for slight abnormalities in bristles or wing veins, which are quite common in wild populations. Such genes are linked, that is to say are handed down together, and the harmless variations thus serve as indices of dangerous recessives.

Quite a number of human differences, for example, those between members of the different blood groups, and between those who can and cannot taste phenyl-thio-urea, are due to very common gene substitutions. It would be perfectly practicable to discover a large number more of such genes. Indeed, they were being discovered at a considerable rate by a German worker until political events put an end to his research. I should estimate the cost of an investigation which would give us a sufficient background of normal genes for linkage work at between £3000 and £5000 provided the right men were chosen

for the work, and a number of families were available through co-operation with some hospital or authority.

Except with such aid I see little chance of investigating the problem of congenital mental defect. We already know that mental deficiency is due to very many causes; and naturally enough. There are some hundreds of causes of blindness; and the cerebral cortex is a more complicated organ than the eye, and therefore likely to work badly for a greater variety of reasons.

Of so-called congenital cases of defect some are due to injury at birth, some to infection, especially syphilitic. Here it is worth noting that chemists are only permitted to sell antiseptics for the prevention of that disease if no instructions as to their use are sold with them! This curious example of censorship doubtless accounts for some mental defect. Other types of defect, particularly 'mongolism', are caused by prenatal environment rather than heredity. Of the truly innate types of mental defect some are due to dominant genes, as shown by their transmission to the offspring, some to recessive genes, as shown by the frequency of inbreeding among their parents. In most cases we have no definite information, and shall not until we can distinguish the different causes by clinical or genetical research. Quite recently Fölling* found that 10 out of 430 defectives, and no normals, excreted phenyl-pyruvic acid. Here the mental defect was probably due to a metabolic error, and this latter very possibly to a recessive gene.

Now a proportion of mental defectives which different authors place between 5 per cent and over 50 per cent, are derived from defective parents. Thus if all defectives were prevented from breeding, the number of defectives

* Fölling, A. (1934). *Zeit physiol. Chem.*, 227, p. 173.

in the next generation would be reduced by a proportion which I do not personally think would exceed 20 per cent. The dominant genes concerned would be abolished, but the recessives would remain. This result would be worth while, but would not abolish mental defect, and would be slight compared with other equally practicable results, such as the abolition of venereal diseases, which would also involve some restrictions on liberty.

There are several objections to the policy of wholesale sterilization which has been suggested. The operation is trivial for men, but for women it is about as serious as that for appendicitis, and there would inevitably be occasional fatalities. Any attempt to make this operation compulsory or even alternative to seclusion in an institution would be a violation of the principal of the sanctity of human life, which underlies so much of our legal practice. Except as a punishment for murder or treason the law does not permit that people should be killed, though it permits an operation risking their lives in order to eliminate a graver risk. If a government once violates this principle it is opening the door to very serious consequences. Our more intelligent politicians realize very well that if the government starts killing people, people will sooner or later start killing the government. Hence it is to be hoped that they will not legalize such operations as salpingectomy on imbecile women, even if it is done with her consent. The consent of a mental defective is not worth very much.

Another objection is that we have no adequate criterion of mental defect. The late Professor Trouton did not learn to read until the age of 12. If he had been an elementary school child he would have been sent to a special school for defectives. He was so far from being

defective that at the age of 17 he discovered the law which bears his name.

Sterilization would not be carried out without class discrimination. Idiocy and imbecility are about equally common in all classes. Certified feeble-mindedness is commoner among the very poor. While genuine mental defect may be rarer, it is obvious that it is often not certified among the rich, although a glance at the press will convince anyone that they include a number of persons who satisfy the legal criterion of imbecility in that 'they are incapable of managing themselves or their affairs'.

It is worth pointing out that where mental deficientes are sterilized this is done from economic as well as from biological motives. Judge Holden of Yakima, Washington, U.S.A., sentenced John Hill to a sentence of from 6 months' to 15 years' imprisonment for stealing hams, the sentence being suspended during his good behaviour. He also suggested that Hill should be vasectomized, to which he consented. What follows are the judge's own words:*

Hill, his wife, and five children, are all mentally subnormal, even for their situation in life. For many months the children have been half starved and half clothed . . . The case was brought to the attention of the public authorities through the discovery of the theft of the hams, since which time he and his family are partly dependent on public charity, and without the addition of more children to the family, will undoubtedly continue to be more or less of a public charge; with more children the extent of demand on public charity will be increased.

It did not occur to the judge either that there might be

* Laughlin, C. (1922). *Eugenic sterilization in America*. Chicago (p. 92).

any connexion between the starvation of children and their mental dullness, or that there was anything wrong with conditions under which a beet-sugar labourer could not earn enough to support five children.

It may be necessary that the richest country in the world should sterilize its citizens as a measure of economy. But at least it is to be hoped that if Britain follows the example of Washington the suggestion will not be made that such action is taken in response to the demands of biologists. Biologists may legitimately demand that a proportion of mental defectives should be prevented from breeding. The demand that they should be sterilized comes from those who consider such a measure to be cheaper than segregation, and to whom this consideration is paramount. But there is, I think, a real case for legalizing the sterilization of those who desire it, if they carry a sufficiently harmful dominant gene, such as those for some forms of cataract, blue sclerotics with brittle bones, epiloia or lobster claw. Such a measure seems desirable as an addition to our liberties whose effects would be biologically advantageous.

Besides demanding sterilization and similar measures for defectives, many eugenists hold a doctrine which may be stated as follows: 'Men and women born into one economic class are constantly passing into a richer one if they possess more innate intelligence than the average of their class, into a poorer one if they possess less. But the poor breed faster than the rich. Hence the innately stupid breed faster than the innately clever, and the mean innate ability of the population is falling.' Before examining the proposed remedies for this situation I must consider whether the fundamental proposition is true.

At first sight it appears obvious, but there are two good reasons to doubt it. In the first place it is clearly flattering to the self-esteem of those who hold it, and therefore suspect. Secondly, if it were true, a system which allotted a number of wives to people who made money would clearly tend to produce a race of great ability, at least in commercial matters. Now this system has been tried, and what is more, tried with an adequate control. In Mohammedan countries during the last twelve centuries followers of the Prophet who have acquired wealth have practised polygamy, while their poorer co-religionists have had one wife or none. On the other hand, Christians and Jews in Mohammedan countries have been on the whole monogamous, even if the rich had some illegitimate children. Hence we should expect that Mohammedans would have acquired greater commercial ability than members of other religions, in fact that a Turk would generally beat a Jew or an Armenian in a commercial deal. This is not the case. Hence I do not regard it as certain that if in England the rich bred faster than the poor our race would acquire greater innate ability, even of that particular kind which leads to a rise in the economic scale.

I wish to suggest that the phrase 'innate ability' is meaningless. We cannot say that in all environments A will prove abler than B by any particular test, save in exceptional cases, as when B is a microcephalic idiot. An analogy from agriculture will make my case clear. Put a Jersey cow and a South African scrub cow in an English meadow. The Jersey will give far more milk. Put them on the veldt, and the Jersey will give less milk. Indeed, she will probably die. The Jersey has been selected, not for high milk yield in all environments, but

for a yield which varies more than that of the primitive cow in response to environment.

A number of writers on eugenics have dealt with the so-called 'social problem group', men and women who are petty criminals, unemployed even in times of prosperity, more fertile than the average, and on the whole endogamous. There is evidence that their behaviour is partly due to inherited dispositions, and it is assumed that they would be socially inadequate in other environments, as they are in the slums. I think this far from certain. They include some real defectives, but the rest, for all that anyone knows, may be like the Jersey cows on the veldt, yielding little of value in their actual environment, but possibly capable of better things if they got out of it than men and women who are more contented with social conditions as they exist in the slums. It is only when people have failed in a favourable environment such as we may hope to see throughout Britain in the future that they can be regarded as probably unsuitable parents of future generations. Differences within a social class are far more likely to be heritable than differences between members of distinct classes.

I know that most writers on eugenics disagree with me, and I will briefly examine the consequences to be drawn from the theory that as regards human achievement the effects of nature and nurture are additive, even though they are not so as regards the yield of cattle or wheat.

If the well-to-do are innately abler than the poor it is desirable that they should breed quicker. They appear to breed more slowly for several reasons. They are more cautious, have greater knowledge of, and opportunity for, birth control, and carry more genes making for low fertility. This last characteristic is due to the fact that low

fertility is inherited, and makes for economic success, as is obvious if we compare the possibilities of saving money open to a man with two children, and a man with ten. In this country it has been specially stressed by R. A. Fisher.*

In view of our already inadequate birth-rate no proposal tending to reduce the existing fertility of any classes not definitely defective can be seriously entertained. A system of family allowances would have in Fisher's view three distinct advantages.

In the first place it would check the coming fall in our population. In the second it would act most sharply on the fertility of those who now limit their families on economic grounds, and are regarded by most eugenicists as possessed of better innate endowments than those who breed more freely. And thirdly, by checking the social promotion of infertility as such, it would end the present sterilization of ability. For, according to Fisher's argument, infertility and ability equally lead to a social rise, and hence, as people generally marry within their own social class, genes making for ability and infertility are associated in the same families, and thus the genes making for ability tend to disappear.

There is, however, an argument for family allowances which appears to me very much more cogent. In the last twenty years we have, for the first time, arrived at definite criteria of a satisfactory diet for human beings. We know that a very great deal of our existing physical defects are due to qualitative as well as quantitative under-nourishment.

Qualitative under-nourishment is not confined to the

* Fisher, R. A. *The Genetical Theory of Natural Selection*. Oxford, 1930.

poor. But it is certainly far commoner among the poor than the rich. And in a family with a sufficiently small income it is impossible to avoid it. There is surprisingly little controversy as to the minimum cost * of an adequate diet for children under English urban conditions. The British Medical Association's Committee find that this rises with age from 2s. 8d. to 5s. 5d. per week. Professor Bowley's standard, including less milk, rises from 1s. 10d. to 4s. 8d.

It is at any rate clear that the 2s. per week allowed for the child of an unemployed man for all purposes is entirely inadequate, and that if this sum were raised to 5s. the unemployed with a family of four or five would receive a larger income than many employed men with similar families.

It is not for a biologist to suggest how this situation should be remedied. But if it is not remedied, then the research of the last few years on dietetics has been largely useless, and there appears to be little point in continuing it. Clearly the action of the Government in lowering the price of milk to school children is an example of one possible method, which if properly carried out will tend to canalize the demand for foodstuffs into channels approved by biochemists. It is a compromise between allowances and rationing.

But though it is a great step forward it is very far from adequate. A definite standard of diet is available, and no biologist should be satisfied until it is reached. It is worth noting, by contrast, that no similar standards can be given as regards housing or clothing. A biologist may demand the abolition of slums, but he cannot say what constitutes a slum, while he can say what constitutes an

* In 1934.

inadequate diet. In the future scientific standards of housing may be attainable, but they are not as yet.

I have tried to show that three different arguments may be brought forward for some form of family endowment. In the first place an adequate diet is now as much part of preventive medicine as an adequate water supply. Secondly, our population is likely to decline rather rapidly unless the present economic incentives to family limitation are removed. Thirdly, such a measure would check the association of innate ability with infertility which is thought by many eugenicists to exist. For the last two purposes family allowances would have to be roughly proportional to the family income. Fisher regards 12 per cent per child as adequate; other authors would give a higher figure.

It is not for me to say whether adequate family endowment is compatible with our present economic system. There are good reasons to doubt it. If our rulers tell us that it is impossible under capitalism, then we had better try socialism. However, it can also be argued that an assured effective demand for a certain minimum would tend to stabilize capitalism, and that the existence of even our present biologically inadequate minimum in Britain has stabilized it.

Whichever of these alternatives is true, I am certain that as biologists begin to deal with human problems they will increasingly demand a minimum dietary for the whole population, and a system of family endowment which will counteract the existing trends in our population.

I have not had time to deal with the racial question. A good case can be made out for discouraging immigration of negroes into Europe, or of Europeans into tropical

Africa, since in each case the immigrants are ill adapted. Unfortunately as the result of political factors there are far greater difficulties in migration between England and Denmark than between England and Nigeria. No serious case against migration can be made as between the different genetical types (I hesitate to use the word 'races') who have lived in Europe for many centuries.

There is, of course, a strong case against the admission of persons of whatever race who are physically or mentally below the average. On the other hand, the opportunity has arisen, as the result of recent political disturbances in Europe, of admitting to British citizenship exiles of proved intellectual ability. Every eugenist should be prepared to recommend the admission to British citizenship of such exiles, provided that they attain a sufficiently high standard.

I fear that I have said little that is novel, nor have I offered any particular panacea. The application of the data of human biology to politics and ethics will probably be more complex than that of the data of physics to industry. It is very important, if the whole science is not to be discredited, that premature steps should not be made, and that biology should not be harnessed to the car of any political party. For the latter reason I have here suppressed many of my own views, for example, the opinion that our existing society is biologically unstable, and have tried rather to stress those opinions which enjoy a sufficiently general support to render them worthy of consideration not only by biologists, but by politicians of whatever outlook.

AFTER-EFFECTS OF EXPOSURE OF MEN TO CARBON DIOXIDE *

by W. ALEXANDER, B.SC., P. DUFF,
J. B. S. HALDANE, F.R.S., G. IVES, and D. RENTON

IN connexion with the loss of H.M. submarine *Thetis*, it was desired to determine the effect on men of breathing oxygen in an escape apparatus after prolonged exposure to air containing high carbon dioxide and low oxygen. The air in the submarine was under a pressure of about 8 cm. Hg above the atmosphere, the volume per man being 4710 litres. From the accounts of survivors it was judged that when they left the sub-

* This article, reprinted from the *Lancet* of August 19th, 1939, is the only one which I have written concerning the *Thetis* case. As this is still *sub judice*, further comment might be illegal. When the findings of the court of enquiry on the disaster are issued, I hope to comment on the case more fully. It will be remembered (except by readers of such papers as *The Times*, which did not mention the fact) that my colleagues, Alexander, Duff, Ives, and Renton, are former members of the British Battalion which was recently fighting on behalf of the Spanish Republic. Alexander commanded the battalion for some time. At the time of the experiment Renton was out on bail. As a leader of the unemployed he had been one of a party which entered the premises of a railway company in an effort to show that they were 'genuinely seeking work', and he was on trial for this offence.

I chose these men as colleagues because I had no doubt of their courage and devotion. Men with such qualifications were, however, refused admission to the Territorial Army. They also possessed the genuine scientific spirit, and took notes on their own initiative, though towards the end of the experiment these became rather erratic.

Besides the experiments here described, two others were done to

marine after 17-18 hours' confinement the partial pressures were approximately: CO_2 , 6 per cent, O_2 , 16 per cent, $\text{N}_2 + \text{A}$, 87 per cent of an atmosphere.

J. S. Haldane or Lorrain Smith (1894) breathed air in a closed chamber for $7\frac{1}{2}$ hours until the CO_2 rose to 6.4 per cent, and the O_2 fell to 13 per cent. On emerging he had a headache and vomited. J. B. S. Haldane (1924a, 1924b) had the same symptoms after $1\frac{1}{2}$ hours' breathing air originally containing 5-6 per cent CO_2 and in which the CO_2 rose to a maximum of 7.3 per cent. He always vomited when the final percentage exceeded 6.5.

On the other hand, Long (1924) had observed headache and nausea in two subjects breathing mixtures of CO_2 and O_2 in which the maximum CO_2 percentage was 11, and the maximum time of exposure 50 minutes. He

duplicate, if possible, certain details of the *Thetis* disaster. These experiments had little biological interest. I must apologize for the style of this article, which is that generally adopted in scientific communications. On the other hand, it may, for that very reason, be of interest to readers who have never opened a medical or scientific journal. The chemical formulae have the following meanings:

CO_2 , carbon dioxide; O_2 , oxygen; N_2 , nitrogen; A, argon; NH_4Cl , ammonium chloride; NaHCO_3 , sodium bicarbonate; pH, hydrogen-ion potential (one of the exact measures corresponding to the rather vague word 'acidity').

I am glad to be able to reprint this paper, as it may serve to correct the somewhat sensational accounts of these experiments which appeared in the press. In carrying them out I was acting on behalf of the Amalgamated Engineering Union and the Electrical Trades Union, some of whose members had been killed in the *Thetis*. I did not run any appreciable risk, as I already knew the effects of such gas mixtures on myself. However, in view of the different effects of carbon dioxide on different individuals I was aware that my colleagues were in greater danger than I. Fortunately none of them had any serious after-effects. Such effects would be expected in the case of ordinary men, of whom an appreciable fraction are psychologically upset by experiences of this kind.

did not record any aggravation of symptoms on breathing fresh air, though the symptoms continued for some time. The additional O_2 may have been responsible for this difference. It was therefore considered probable that the men in the *Thetis* suffered from headache and/or vomiting on breathing pure O_2 in their escape apparatus, these symptoms being due to the sudden fall in the CO_2 and not to the rise in O_2 breathed. However, it was clearly desirable to find out whether an aggravation of symptoms was normal in such circumstances.

The Present Experiment

Messrs. Siebe Gorman & Co. kindly put a steel chamber of 5800 litres' capacity at our disposal. The conditions in the *Thetis* were duplicated as far as possible, the pressure being kept at about 1.1 atmospheres, and the CO_2 brought up to between 6 and 7 per cent, whilst the oxygen fell correspondingly. The figures given for CO_2 are partial pressures, that is to say, percentages multiplied by 1.1.

A preliminary experiment was done to determine whether a gradual rise in CO_2 pressure had the same effect on J. B. S. H. as an abrupt rise.

He let N_2 and CO_2 into the chamber at 10.10 P.M. and the pressure was adjusted so that the partial pressure of CO_2 was 2.5 per cent, that of O_2 being about 20 per cent. The CO_2 then gradually rose and the O_2 fell owing to his breathing. The pressure fell from time to time owing to a slight leak, but was kept up with compressed air, so that the vitiation of the air followed much the same course as in a submarine. The dry-bulb temperature varied from 70° – 74° F., the wet bulb being 2° – 4° lower.

J. B. S. H. slept intermittently from 12.30 to 8.30 A.M. when the CO_2 pressure was 5.1 per cent. Panting was marked, but there was no distress. At 10.50 the CO_2 had reached 5.8 per cent and the panting was severe, with slight headache, photophobia, and transient nausea. At noon the respirations were 44 per minute, but the pulse-rate was only 60, as compared with a normal figure of about 75. At 12.40 the CO_2 had risen to 6.6 per cent, and there was slight confusion, though the headache was not severe and there was no vomiting. He left the chamber, and put on a Davis escape apparatus.

After 2-3 minutes he removed the mouthpiece in order to vomit, which he did at intervals, probably bringing up about a pint of clear fluid. He had not eaten or drunk for the previous 16 hours, in order to parallel conditions in the submarine. A violent headache developed, mainly frontal, but somewhat diffuse. This was severe for about an hour, and passed off about 5 P.M. Later he felt unusually well.

Four days later all of us entered the chamber, and remained for one hour in air with a high CO_2 content and correspondingly low O_2 . The partial pressure of CO_2 was originally 6.1 per cent, but rose rapidly. After half an hour air was added and the pressure lowered, but at the end of the hour the CO_2 pressure had risen to 6.7 per cent. Unfortunately duplicate O_2 determinations did not agree, and the partial pressure of O_2 may have been as high as 18.7 per cent.

At the end of the hour all were panting severely, and P. D., who was awaiting operation for the sequelae of five wounds received in Spain, was in considerable distress. On leaving the chamber all except J. B. S. H. put on Davis escape apparatus. W. A. removed the mouth-

piece almost instantly, and vomited repeatedly, though he had had no food since a light breakfast seven hours earlier, and is a good sailor and does not vomit readily in other circumstances. He had a moderate headache. P. D. and D. R. had very severe headaches developing within a few minutes, and both were temporarily incapacitated. J. B. S. H. and G. I. had slight headaches developing after 10-15 minutes. All had recovered after 3 hours.

The slightness of J. B. S. H.'s symptoms on this occasion suggests that the after-effects depend on the time over which air containing above 5.5 per cent of CO_2 is breathed, rather than on the concentration at the end of the experiment. It is, however, possible that on the occasion of the second experiment he was acclimatized to some extent. In view of his experience in 1923 this is unlikely.

Discussion

In each of six persons who have breathed air containing CO_2 at a partial pressure of over 6 per cent with normal or subnormal O_2 , for an hour, there has thus been an aggravation of symptoms other than panting, when air or O_2 was breathed, and three out of the six have vomited. On the other hand, there are marked individual differences in the symptoms. J. B. S. H.'s slight symptoms in the second experiment may have been due to his previous experience, but this could not apply to G. I., since none of the rest of us had ever taken part in tests of this kind. Similarly P. D.'s severe headache may have been partly due to his ill health. But this could not apply to W. A. and D. R.

It will be remembered that at least one of the men who

tried to escape from the *Thetis* pulled off the mouth-piece of his escape apparatus and was drowned, and that only 4 out of 103 succeeded in escaping. It is suggested that some of the remainder were incapacitated by vomiting or other symptoms. It seems that in such circumstances men should breathe air or oxygen for 30 minutes or more before attempting to use the escape apparatus under circumstances where vomiting is fatal, and where calmness and some physical exertion are required.

It must, however, be emphasized that the experiments here described were conducted hurriedly, so as to permit one of us to give evidence at the judicial enquiry. There can be no doubt that experiments more scientifically carried out, on larger numbers of men, would give more definite results. Moreover, a careful investigation of the vasomotor and other changes involved might throw light on the causes of headache. This can hardly be due to a sudden increase in the alkalinity of the tissues. For J. B. S. H. has frequently overbreathed so as to render himself so alkaline as to develop tetany and excrete a urine containing so much bicarbonate as to froth on adding acid. This has never produced a headache. On the other hand, on one occasion he produced a severe acidosis with NH_4Cl . He then ate about 40 g. of NaHCO_3 to restore his pH to normal. This produced a severe but transitory headache, perhaps analogous to that here described.

Summary

After breathing air with a partial pressure of over 6 per cent of CO_2 for an hour or longer, five men experienced headache on breathing oxygen, and two of

them vomited. The bearing of this observation on escape from submarines is discussed.

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SOCIETY AS A BIOLOGICAL EXPERIMENT

MOST animals live either alone or in family groups consisting of one or two parents and their offspring so long as the latter are dependent. A few are aggregated into larger societies. These again are of several types. They may be greatly enlarged families consisting of a parent and very numerous and active offspring, like a wasps' nest. Such societies imply the specialization of a few individuals for reproduction, and are therefore unlike any actual or possible human community. Among societies where there is no reproductive specialization we have at one end of the scale large groups with complete sexual promiscuity like a shoal of herrings, at the other monogamous unions only ended by the death of one partner, such as are found among many birds. Between these there are all kinds of intermediates; for example, small aggregates of mated couples like a rook colony, groups which unite temporarily for a special purpose such as migrant bird swarms, and many other types.

Where do human societies fit into this classification? The answer is not simple. A civilized man does not belong to one society only. During most, but seldom during all of his life, he belongs to a family or some other small organization (e.g. a club or an artel) practising some form of internal communism. He belongs to a group of producers which is now rarely coextensive with the family. He belongs to a nation. And he belongs to the

world economic organization. This last fact is particularly important in a country like England, whose dependence on imported food is a hard biological fact.

All forms of society larger than a tribe of a few dozen families represent an experiment made in the last ten thousand years. What has made them possible? The primary cause has been the extension of human society to include the domesticated plants and animals. This has made it possible to increase the density of human population subsisting on a given area of land several hundred-fold. And this mere quantitative change has brought about a change in the quality of human intercourse. In fact, it has made society, in the sense of an organization beyond the family or small tribe, a necessity. Society may be defined as man's reaction to the increased density of population which began in neolithic times with domestication. A people of hunters can, at best, only develop complex social organization during the brief period when they co-operate for some great purpose like the annual buffalo hunts of the Indians of the North American plains. An agricultural community cannot avoid a high degree of social complexity, even though, until fairly definite class distinctions develop, a state is probably rarely if ever developed. Anarchism has been out of date since palaeolithic times.

Besides domestication, at least two other important causes have contributed to the formation of society. One is a change in tradition. By this word I mean all forms of behaviour handed down from one generation to another, including language, techniques of agriculture and industry, morality, religion, beliefs, and organizations: in fact, all features of human existence which are not determined by biological heredity on the one hand, or the

natural environment on the other. The other cause is a change in human nature, that is to say, in the characters determined by biological heredity. The extent of this change is highly questionable. Beyond doubt our innate immunity to disease has altered. It is much less sure whether those innate dispositions which, interacting with the environment, determine our moral and intellectual activities, have changed to any great extent.

In the last few centuries a fourth set of causes has come to mould the form of society. We are becoming increasingly dependent on machines which cannot be manufactured without a great deal of co-operation. This calls for a far more complex form of production, and therefore for a far more integrated society, than was needed in a community based on agriculture and handicraft. It also makes a greater density of population possible. Both the complexity and density raise problems which are still unsolved.

Now when we consider the biology of human society we must be very careful to limit ourselves. Biology is and must be materialistic. This does not, of course, mean that it must be mechanistic. But so long as we are biologists we are considering men as animals. The biologist should not try to do the work of the psychologist, economist, or sociologist. He can very frequently tell them where they are wrong. He must not try to tell them where they are right. He can tell the economist what food a population needs, and whether a given agricultural system will provide it. He can tell him that farm labourers live longer than urban workers, and coal-miners than potters. But he cannot add that, therefore, as many people as possible should go back to the land, or that the pottery industry should be abolished. That

would only be admissible if it were agreed that long life was the only thing worth having. He can say (though not, I think, on very adequate evidence) that, by certain radical interferences with our existing system of reproduction, the health or intelligence of the population could be improved. But family life, sexual love, and personal freedom are good things (or at any rate things desired), and it is not the duty of the biologist, as such, to weigh them against hygiene or intelligence.

On the other hand, he can, and should, point out the biological consequences, measured in terms of life and death, health and sickness, increase or decline of population, of various social measures. And it is futile to suppose that in doing so he can write or speak as if he were discussing an ants' nest. He is himself a member of a particular society, and a member of a particular class and profession within it. The first prerequisite for a relative objectivity is to realize that these facts make an absolute objectivity impossible.

Let us now consider our field of enquiry. The biological needs of human beings as individuals are air, water, a temperature within a certain range, food, and protection from violence and poisons on the one hand, and from parasitism by smaller organisms on the other. Given these, the individual can live healthily if not always happily or morally. If society is to go on, its members must reproduce, and in the long run births must balance deaths very exactly. (The closeness of the balance may be realized by the fact that a community which increased by 10 per cent per generation would increase ten thousand-fold in 100 generations, while a 10 per cent decrease would reduce it to less than one thirty-thousandth.)

So much for mere existence. Society also demands a

certain standard of quality in the individuals composing it. But here at once we get on to debatable ground. Do we want a population of athletes? Or is muscular development a waste of time for city dwellers? Do we want a high general level of intelligence? Or is not intelligence a handicap for those engaged in certain monotonous and menial tasks? These are not questions which the biologist as such can answer. But he can, at least, put them clearly to the politician, though he is most unlikely to get a clear reply.

Let us go over our primary needs. Almost everyone gets enough air, though it has to be forced down shafts of collieries to reach coalminers. The air of ill-ventilated houses and factories is dangerous, not because of the lack of oxygen in it, but because of the disease germs, dust, and other poisons. Similarly with water. Few civilized people die of thirst. A great many die because their water supply has been contaminated with dangerous bacteria.

We keep the air next to our skin at a satisfactory temperature by means of clothes, houses, and heating apparatus. Thanks to these, men can live in every region of the earth. It is generally believed that climate plays a big part in shaping the various human races. In the last few generations climates have become more and more artificial. The climax is reached in North America, where, during the winter in many regions, the climate is arctic out of doors and tropical indoors. No human race has ever lived in such a climate before. Within a generation, the development of refrigerators should make it possible to cool houses in the tropics. This will give us another new and experimental climate.

Food is put to three uses in the human body. It is

required for fuel, for maintenance, and for growth. The fuel value is measured in calories (heat units), and the amount needed depends largely on how much work is done. For fuel purposes one food can largely replace another. When it comes to maintenance and growth, about thirty different substances are needed in the food and perhaps more. Some of these are inorganic elements such as chlorine, potassium, iron, and zinc. Others are fairly complicated organic substances, including the so-called vitamins. When the fuel value or the amount of any of the chemical essentials falls below a certain level, we die. But this minimum level is often far below that needed for perfect health, and most people are somewhat short of one or more of the essentials. For example, most middle-class women in England are short of iron, as shown by the fact that if more iron salts are added to their diet they make more blood. In the working class things are naturally worse.

We already know most of the essentials of diet, and can generally say whether a given diet is satisfactory or not. In another fifteen years our knowledge should be complete. And in industrialized countries most people buy their food instead of producing it themselves. It is thus becoming possible to ensure that everyone should have an adequate diet. But nowhere is the knowledge put into practice. The nation which first does so will undoubtedly raise the standard of its health to an immense extent. But such an achievement will mean the scrapping not only of our present wage system, but of the housing system which involves the provision of meals by each family independently.

Meanwhile, however, the view is generally held—and many who do not formally hold it, vote for it—that the

provision of a proper diet is no part of the State's business. It is generally admitted that in England neither the unemployed nor the worst-paid workers can afford an adequate diet for their children, but it is thought that other forms of expenditure are more important than that needed to feed these children.

Industrial civilization brings with it a new group of dangers from violent death, in particular, factory, mining, and traffic accidents. A good deal of effort (though in my opinion not enough) is being made to keep them down, and they certainly do not occur on a scale large enough to be a serious danger to the stability of society. Violent death in war is another matter, which will be dealt with later.

In the past the principal check to urbanization has probably been disease. If men or any other animals are overcrowded, the spread of infection among them is enormously facilitated, and in any large town the death-rate can only be prevented from outstripping the birth-rate by artificial means.

Infectious diseases may be divided into four main groups. The organism causing them may be passed from one person to another by water and food, by insects, by contact, or by air. The list is not exhaustive but covers most of the great killing diseases. Some may be carried in more than one way. Thus diphtheria can be transferred by milk, air-borne drops, or by such contact as kissing.

If a family lives on an isolated farm no great harm is done if their water supply comes from a well contaminated by their own sewage. A water-borne outbreak of typhoid fever can only arise from a visiting carrier, and will not spread beyond the family. But in a town with

wells and no sewers, a single case of typhoid or cholera may infect thousands.

There are two methods of preventing such diseases. Water may be brought from an uncontaminated source, as in modern towns, or it may be drunk as beer, wine, or tea. Under the Roman Empire, almost every large town had a water supply brought by aqueduct, and this made a considerable increase in size possible. With the destruction or disuse of the aqueduct the population inevitably declined. The universal consumption of beer did a great deal towards allowing populations to increase once more. To-day, however, beer is out of date as a prophylactic against water-borne diseases.

Insect-borne diseases include malaria, carried by the mosquito, typhus fever by the louse, and plague by the flea. The former is the curse of irrigated tropical lands, and probably accounts for the repeated conquest of their enfeebled populations by small bands of invaders from hill or desert countries where mosquitoes cannot live. The louse can be eliminated by frequently washing the body, and particularly the clothes. Bubonic plague is borne by rats, and is therefore not a menace in properly constructed houses where food is not left lying about.

We have not yet solved the problem of air-borne diseases, as was shown by the influenza pandemic of 1918. But we can very greatly check their incidence by diminishing overcrowding. Contagious diseases such as syphilis have been historically important, killing or maiming whole populations in the past. Where transmission is venereal, their spread can be prevented by chastity or antisepsis.

Until the nineteenth century, there were no rational means of preventing disease, and the fate of a civilization

might be determined by an apparently trivial custom. Our traditions regarding cleanliness, which, according to the Freudian psychology, play so great a part in determining our psychological development, are in no way rational. They have rather survived by natural selection. Only in a culture where certain forms of cleanliness were obligatory could dense populations remain comparatively free from a large group of diseases.

If civilization is ever based on reason, the sight of a mosquito in a tropical country will arouse the same emotion as that of a decaying corpse, and we shall be as shocked by overcrowding in our houses as by open sewers in our streets. Meanwhile, the tendency is rather to link up hygienic observances with the feelings of disgust at certain smells which are inculcated in infants. In consequence, a good many so-called hygienic measures are thoroughly superstitious.

In a society with a given system of production there is a certain population in a given area which is better off than would be a smaller or larger population. The exact size will, of course, depend on the standard of well-being adopted. Thus a denser population might have a higher average income, but a greater death-rate from disease. It is worth noting that we cannot decide on an optimum population at present because the conditions of production and trade are changing so rapidly. London is probably over-populated as things are. But it would not be if the population were concentrated in skyscrapers, leaving room for broad streets and for numerous gardens and playgrounds. Germany is overpopulated if it is to be economically self-sufficient, but could comfortably support a larger population if, like England, it traded manufactured goods for large amounts of foreign-grown food.

In the long run, as we saw, births must balance deaths very closely. In the past, a high birth-rate has balanced the high death-rate. During the nineteenth century the death-rate fell earlier than the birth-rate, and the populations of most civilized countries increased enormously. The birth-rate has now fallen, so that, although the populations of civilized countries are generally increasing, the fertility of women is not sufficient to keep up the population in the near future. That is to say, a million girl babies born in this year will have less than a million daughters unless they are, on the average, more fertile than their mothers. Where the population is not falling this is because of the large proportion of women of child-bearing age.

We do not know the reason for this fall. It is certainly not due entirely to contraception, as is shown by the fact that it began in southern Ireland, where contraception is almost unknown, earlier than in any other European country. But beyond question contraception is partly responsible. The fall is also due to the tendency to postpone marriage, but probably a great variety of physiological and psychological causes are at work.

Some fall in the birth-rate prevalent in the nineteenth century was needed if the planet was not to become a vast slum. But the compensation has gone too far. The present Italian and German governments have tried to check the fall in the birth-rate. The former has failed; the latter succeeded during its first three years, but it is too early to say whether the birth-rate will not fall again to its pre-Nazi level.

One question of extreme interest, which will not be answered for a generation, is this: 'Will industrialism be followed by a great fall in the birth-rate in the Soviet

Union as it has been in Western Europe and America? If not, the Soviet Union is likely to dominate the world for this reason alone.

The most striking feature of the situation is that to-day we are ignorant of the causes which govern the birth-rate of a community as we were ignorant a century ago of the causes which govern its death-rate. Until we can control the one as we control the other, society will be a biological experiment performed on men rather than by men.

Men differ as regards their innate characteristics. Some, for example, are born blind, or with such a constitution that, in the existing state of medical science, they are destined to blindness. Others are born destined to idiocy, though once again it must be remembered that in many cases they could be saved from this fate if we knew enough.

Similarly, certain people are born with the capacity, in a given environment, to become powerful for good or evil. It is doubtful whether we can say that any particular innate disposition is always desirable. The combination of intelligence and aggressiveness may give a great constructive statesman or a bloodthirsty tyrant. We know that we do not want physical or mental defectives. We do not know what kind of innate characteristics we want. It is perfectly conceivable that a sudden rise of 10 per cent in the intelligence quotient of the rising generation in England would precipitate a bloody revolution. And only a small minority want such a revolution.

In the same way we do not know how most socially important innate characters are inherited. Let us take the simple case of criminality. This often runs in families, and is generally associated with fairly low, but not ex-

tremely low, intelligence. Where a child follows its parent in a criminal career, this may have been due to an innate deficiency in self-control, or to an innate tendency to imitate the parent, which, on the whole, makes for social stability. We do not know whether the child who becomes an intellectual if brought up in cultured surroundings would not have been a complete failure in a slum. And it will be the task of the psychologist rather than the geneticist to answer such questions as these.

It is, however, certain that different sections of the population reproduce at very different rates. The attempt was made in Hindu India to divide the population into a number of castes, so that occupation and social status were hereditary. Members of different castes did not intermarry, but they interbred to a certain extent. It is probable that innate abilities differ somewhat between different castes. A similar attempt is being made in some countries where different races live together. Thus, in South Africa and Australia, unions between Europeans and blacks are now forbidden.

A society of this type is really a compound of several different biological units. It is clearly a more precarious experiment than a society of the normal kind. Thus if one stratum of it increases more rapidly than another, the equilibrium will be upset. And unless supported by an *ad hoc* religion, as in India, it is likely to generate hatreds which will ultimately wreck it, unless the conquered race dies out, as may well happen in Australia.

Where the society is stratified into classes, but members may move from one class to another, things are rather different. Social rise or fall is at least partly due to innate characteristics. At present in most European countries, and in North America, the poor breed much

more rapidly than the rich, and this is not offset by their slightly greater mortality.

It is claimed by most eugenicists that, on the average, the rich are innately superior to the poor, and particularly so in those innate factors which make for intelligence. If this is so, the populations of most civilized countries are getting innately stupider. Similarly, it is claimed that ill-health leads to poverty, and thus selection favours ill-health. It is also obvious that war is dysgenic where conscription is involved, since congenital defectives, e.g. blind men and deaf mutes, escape.

It is beyond dispute that social success and biological success, in the sense of leaving a numerous progeny, are negatively correlated. In so far as social success depends on inherited factors, these factors are dying out. This state of affairs is not peculiar to our civilization. In medieval Europe the most admired quality, sanctity, involved celibacy. In the Soviet Union the communist leaders seem to have fewer children than the average. Lenin had none.

If in any society the hereditary make-up most favourable to carrying out the ideals of that society is gradually weeded out, the society in question must, it would seem, be biologically unstable. It has been claimed, without very adequate evidence, that the collapse of former civilizations has been due to this type of selection. As our own society is showing symptoms of instability due to other causes, this particular question need not perhaps concern us greatly to-day. However, any society which was planned for stability would have to deal with this biological problem.

The solutions which have been suggested for the problem of the differential birth-rate seem to be mainly

determined by the sympathies of their authors in the class struggle. Some have proposed that the drain of innate ability from the poorer classes should be checked by making a rise in the social scale more difficult. Others hold the view that the birth-rates of different classes would be equalized if the economic differences between them were abolished. It is perfectly conceivable that differential fertility of social groups might be ended either by a rigid caste system or a classless society. If so it must be considered on grounds other than biological which of these alternatives is the more desirable and practicable.

It is, however, by no means sure that the differential birth-rate is undesirable. It can be argued that a rise in the economic scale depends as much, or more, on factors making for aggressiveness than on those for intelligence, and that our greatest need is for individuals whose innate tendency is to be co-operative rather than aggressive.

The opinion is commonly held that only members of certain races can form a society of the highest type. Negroes, in particular, are often regarded as ineligible. Others take the view that all races are equal in their innate capacities. The evidence on either side is extremely slender. It is, however, notable that those authors who believe in the possibilities of dramatic changes in the innate constitution of a race by selection of its best or worst members, commonly hold the view that racial differences are unalterably fixed, so that a negro people could not rise to European standards. This contradiction is readily explicable, since in many countries distinctions of race and class are associated. And on the whole the richer classes are the strongest supporters of

imperialism in states such as England where this is not so.

A final problem arises in connection with war. It is possible that technical developments will render war so deadly as to become a real biological problem. It is not so at present. The available evidence, especially as regards India, suggests that the influenza epidemic of 1918 killed many more people than the World War, and in a much shorter time. As, however, human beings hate one another but do not hate filterable viruses, probably less than a hundred men are engaged in work designed to prevent future epidemics of influenza, while many millions are engaged in 'defensive' preparations.

It may be, however, that before the contradictions which lead to wars between nations and classes are resolved by the establishment of a classless society and a world organization (not necessarily or probably a state), a large enough number of people will be killed in wars to destroy civilization as we know it. If this state of affairs is even approached, defence will become a biological problem. It will, for example, be as essential to protect cities against aeroplanes as against cholera, and the human race will burrow into the earth like so many rabbits.

Two things stand out, I hope, from this discussion. Most human problems are not biological problems. They are psychological, economical, or technical problems. And even within the biological sphere the questions which we ask, and the answers which we get to them, depend on our economic and political orientation.

If the initial premise is correct that society is man's reaction to increased population density, it follows that the most fundamental problems of human biology are

the problems of urban life. It is primarily by their success or failure as experiments in the organization of urban life that the various types of society which are now being tried out on our planet will survive or fall.

A BIOLOGIST LOOKS AT ENGLAND*

To judge from the comments of foreigners from many different countries, it is clear that England stands in need of explanation. The behaviour of the English appears now noble, now base, now stupid, now cunning, but almost always unintelligible. And the English, as compared with many other nations, are peculiarly bad at explaining themselves.

I certainly do not propose to explain England, but I may be able to throw light on a very few of its peculiarities. Let me state some of my qualifications. I have lived there for over forty years, but have only recently come to regard myself as an Englishman. My parents came from Scotland, and I was brought up to regard myself as a Scot. I thus tried to size up the English in a way that few Englishmen would have done. And, having spent some years in Scotland, I had a standard of comparison.

But of late I have come to regard myself as an Englishman because I have come to love England, mainly as the result of owning a motor-car. When I say I love England I do not mean that I love the soul of England, whatever that may be, or the English race, which is, I believe, a statistical abstraction, like the average man or the probability that I shall live till the age of seventy. I am speaking about the country, which has played a large part in making the people, and in turn has been moulded by them. I do not mean that I merely love the beautiful spots such as the upper Thames valley or the Lake District. I

* A lecture delivered to a Danish audience.

get a considerable satisfaction from some of the ugly ones, such as Burton, where we make our best beer, or Stoke, the great smoky pottery town of which Arnold Bennett wrote.

By the word love I mean what I say, an emotion similar to what I feel for my wife, a joyful familiarity. Perhaps one must be somewhat of a materialist to love a series of physical objects, and I am somewhat of a materialist.

Finally as to the motor-car. There is no other way of seeing England unless one is a man of great leisure and strength. A large part of the country has been enclosed by fences, so that one must keep to the high roads in travelling. And we motorists have made them quite intolerable for walkers and cyclists. If you go by train you will have considerable difficulty in getting to some of our most remarkable places, such as Lacock or Cerne Abbas, to mention two at random. Lacock is an almost unaltered medieval village. It contains a very fine Abbey converted into a country house, which is notable because it was the first building in the world to be photographed, and some of the most important steps in the development of photography were made in it. Cerne Abbas boasts of a gigantic figure cut into a chalk hillside before the coming of Christianity, and displaying sexual attributes which the modern inhabitants of the village find embarrassing.

You can motor from any part of England to any other in a day without difficulty. What books you take with you depends on your taste. I never travel without the geological map of England. And I generally take a map of Roman Britain. I like to know that that hill in front of me was once a coral reef in the Oolitic sea, or that

this unexpectedly straight piece of road was built for the Roman infantry to march from London to Caerleon (Castra legionum) where they kept watch on the turbulent hill-folk of Wales.

If you are a bad botanist like myself you will take Bentham and Hooker's *British Flora*. If you are a good botanist you will take Druce's *Comital Flora of the British Isles*, in which the geographical distribution of every wild plant is given. If you are a zoologist or a farmer you will take the Ministry of Agriculture's book *British Breeds of Livestock*, and you will stop your car to identify a drove of New Forest ponies in Hampshire or a flock of Dartmoor sheep in Devonshire. If you are confining your travels to a few counties you will do well to buy one of the county guide-books published by the Shell petrol company. But good guides to architecture and the like are numerous enough.

Whatever his other interests may be, I am convinced that no one can begin to understand England without some knowledge of the soil and the weather. Southern England with Wales is the geologist's primer. Nowhere else in the world will you find such a complete sequence of strata, from the Pliocene of Norfolk to the Cambrian of Harlech, all in their correct order. Indeed, modern geology came into being with the British canal system. The great Smith, an engineer in charge of the canal cuttings, was able to give the first general account of geological succession, in which the principal strata were placed in their correct chronological order.

A geologist might find such a journey dull. The student of England will note how the rocks have influenced the men, plants, and animals who live on them. We start at Harwich on a fringe of tertiary sand and

clays. The beaches lie open to invasion by ships of shallow draft, and the people are predominantly the descendants of fair-haired, blue-eyed Angles and Danes. The houses are mostly of brick, for there is no good building stone within a hundred miles.

As we go westward we rise on to low hills of chalk. They are now often barren for want of water, and the very names of the villages testify to this. We may pass through Westbury Waterless. Farther south we should have found Winterbourne Stoke, Winterbourne Gunner, and many other village of the same name. A Winterbourne is a stream (burn, Brunnen) which only flows in the winter and dries up in the summer. We shall have more to say about this matter when we come to describe the weather; for two thousand years ago these brooks ran all through the year. Now the chalk downs are largely deserted, and sheep graze among the holy places of our ancestors, the stone circles where they worshipped, and the barrows where they buried their dead. This is specially so in the south where the chalk hills are steep. Farther north they have been worn down by the ice which covered all England save a strip along the south coast. The flints from the chalk have not only served as tools for palaeolithic and neolithic man, but as building material for a number of rather charming little churches.

We come down off the chalk on to a belt of clay which has furnished bricks for some of the ugliest villages in England, those of Bedfordshire, and rise again to a belt of low rolling hills of oolite and limestone. This is the land of one of our most characteristic sports, fox-hunting. The low lands are too wet for it, scent does not lie on the chalk, and though there are hunts among the

mountains, where hunters occasionally fall over cliffs, the sport does not exist there in its typical form.

I do not propose to defend fox-hunting. But it is certainly much more defensible than any other blood sports, if only because remarkably few animals are killed. Its delightfully picturesque costume and ritual form a patch of colour in our otherwise rather drab life. And it has inspired, if not some of our greatest literature, certainly some of our most characteristic. Surtees was a somewhat older contemporary of Dickens, and is not perhaps unworthy of being mentioned in the same breath. My wife takes the view that one of his heroes, Mr. Jorrocks, is the Don Quixote of English literature. This fat little grocer becomes master of a very inferior pack of hounds. He possesses neither the physical strength nor the social rank required for such a post. He is continually involved in ludicrous situations, and is even, like Don Quixote, found to be a lunatic. But he is a fundamentally decent man, with a very considerable technical knowledge of hunting, and though we may laugh at him, we love him. In the end, in a characteristically English way, he muddles through, largely thanks to his Sancho Panza, a villainous huntsman called Pigg.

The fox-hunting belt is also the home of England's best domestic architecture. The soft limestones are so kind to the builder that even in the worst period of our architecture, somewhere round 1860, they furnished the material for houses which if not beautiful were at least dignified. Within this area you will find villages in which almost every house is beautiful; outside it there are many noble buildings; but the average house is ignoble to the south and east, gaunt to the north and west, where the stone is too hard to allow full scope for the craftsman.

Interspersed in the fox-hunting country are the coal-mining areas. Above ground you will see great smoky industrial towns and dirty mining villages. But below them is a subterranean country where every man is something of a hero. Coalmining is a dangerous occupation, and the miner has a code of honour as high as that of the sailor. In a maritime nation the sailors keep up the tradition of courage in time of peace. Seamanship is one of the substitutes for war in which man is pitted against nature rather than against his fellows. Coalmining is another such substitute. To the west of the coalmines, and separating the coalmining areas in the north, are older and harder rocks, the mountains of Wales and northern England, and the steep hills of Devon and Cornwall.

I believe that a great many of the peculiarities of England depend on the extreme diversity of its soil. For each soil has its own type of agriculture. Wheat growing is a very different thing on the fens of Cambridgeshire and the chalk uplands of Wiltshire. But perhaps the most striking testimony to the diversity of our soil is the diversity of our domestic animals.

Of sheep alone we have over thirty distinct breeds, each with its own peculiar standards of perfection, and each one showing signs of adaptation to a particular soil and climate. The single county of Suffolk produced its own breeds of horse, cow, sheep, and pig. The Suffolk Punch cart-horse and the Suffolk sheep are still in existence, the Suffolk dun cattle have been merged in the Red Poll, and the Suffolk pig in the large black.

The men and women of England have proved successful colonists. So have its animals. The English Thoroughbred has been the origin of most of the world's race-

horses, and the Shire and Hackney have been of greater practical importance. Australia and New Zealand have been largely colonized by Leicester and Dorset sheep, the United States by Jersey cattle. Our animals have even succeeded, where our men have failed, in colonizing Europe. A good deal of Danish bacon comes from Large White pigs of English origin. At the present moment we are exporting large quantities of livestock to the Soviet Union.

It is commonly believed that the various kinds of wild animals were created by God. If so the men who produce new breeds of animals, men such as Bakewell, who originated the Leicester sheep, and King Charles II, who introduced into England the first Arab horses from which the Thoroughbred was developed, are to be regarded as among the most god-like of men.

But though I think that both by nature and tradition the capacity for animal breeding is very common in our country, I suspect that the diversity of our soil and climate has been largely responsible for our success. For example, our finest poultry breeds such as the Buff Orpington, the Light Sussex, and the Dorking, mostly come from the chalk country south of London, where a very high production of eggs was possible before anyone had thought of adding lime to the ration of poultry to enable them to produce more egg-shells.

I shall try to show later that this same diversity has had much to do with our human characteristics. But before I do so I must consider our weather. England lies in the track of cyclonic disturbances formed where the polar and equatorial fronts meet. So that our weather is extremely changeable. Yet it does not run to extremes. Great droughts and floods are very rare, and our storms

seldom do great damage. We have also been spared earthquakes and volcanoes.

I believe that these facts have had a considerable effect on our ways of thinking. Men tend to attribute the weather to God, or gods. If great floods, droughts, and destructive storms are common the gods are conceived of as cruel or at least stern. If, on the other hand, the climate is generally very reliable, there is a tendency to take the order of nature for granted. But in so far as the English have formed their ideas of God from the weather, they have regarded him as a being who can be relied upon not to proceed to extremes, but yet very uncertain in the details of his behaviour.

A regular course of weather, varied by occasional disasters, must tend to fatalism. An Englishman cannot rely on God to fill his pond this year if he has filled it last year. Yet there will certainly be some rain. Water will be available if he makes sufficient effort. His house will not be destroyed by a tornado, but he must see that his chimney is shored up, or a winter gale may bring it down. The variability of the weather, like that of the soil, has gone a long way to making the Englishman an empiricist. He has a distrust of too broad generalizations. Yet he does not sit down and passively abandon himself to the will of God or the whims of chance.

Our weather is not only changeable from day to day but from century to century. From about 1800 B.C. to A.D. 450 it was much wetter than at present, and the chalk hills and plateaux were much more fertile than now. For example, wells of the Roman period have been found, containing buckets which show that they were actually used. And yet the present water-level is sometimes 100 feet below the bottoms of these wells. The

fortified villages, the tombs, and the stone circles such as Stonehenge make it clear that the chalk country was then much more populous than it is to-day. On the other hand, the valleys were full of forests and swamps, and hardly inhabited. The Angles, Saxons, and Jutes invaded England just after the great change in the weather. They found the lowlands largely unoccupied, and the upland dwellers in the middle of an economic crisis. Hence they were able to impose their language and institutions on the country, as the Germanic invaders of other parts of the Roman Empire could not. The subsequent Viking invaders managed to conquer a good deal of England, and to impose their place names. But their descendants adopted the language of the conquered Angles and Saxons. So the weather has been responsible, not only for some features of the English character, but also for some of the decisive moments in our history.

These considerations bring us at once to the question of the English race. Fifty years ago it was quite easy to answer questions on this subject. To-day, thanks to the work of Fleure, Morant, and a few others, we have learned so many facts that any such simple tale as would please race-theorists is now out of the question.

The British Isles have been repeatedly colonized from Europe, and have contributed very little to the population of the continent. The one exception to this rule is of interest. English and Flemish seamen played a large part in the capture of Lisbon from the Moors and many of them settled down there. It is probable that both their heredity and tradition played a considerable part in the early maritime exploits of the Portuguese.

The neolithic population of England was long-headed. We do not know about their colouring, but many people

believe that they were dark—Mediterranean rather than Nordic. At the end of the neolithic period came the invasion of the so-called Beaker Folk, a round-headed race making a characteristic type of Beaker pottery. They seem to have merged gradually with the former inhabitants. At any rate, during the Iron Age the average skull shape became much more intermediate.

The Nordic invaders during the fair-weather period from A.D. 450 to 1000 were of course long-headed, fair-haired, and blue-eyed. The Norman conquerors were few in number, though, to judge from skull measurements, some of the coast towns of Kent and Sussex seem to have been populated from France.

For the last thousand years our population has been mixing, and since the close of the Middle Ages this mixture has gone on to a much greater extent than in other countries, because we abolished our peasantry. The agricultural labourer has not been tied to one piece of land, either by feudal serfdom or by ownership. The land has mostly been in the possession of large landowners who let it out to tenant farmers. The smaller landowners generally employed a number of labourers.

In a majority of cases the land was acquired by acts of gross injustice. But the fact that agriculture was organized in large units made it progressive, and England led the world in the improvement of agricultural plants and animals, and in the introduction of root crops. Only with the introduction of agricultural co-operation on the one hand as in Denmark, and collective and State farms on the other as in the Soviet Union, has it been possible to combine efficiency with social justice in agriculture. With the mechanization of agriculture our farms have become too small as units, and if our farming is to

become fully efficient once more, we shall have to take to co-operation or socialism.

The biological effect of all this has been an intimate mixture of our population. It is true that on the east coast we have a high proportion of fair and long-headed people, and that dark-haired and round-headed types increase as we approach the Welsh border. Nevertheless, within any small area, say Oxfordshire, we find that there is no correlation between hair colour and head-shape. That is to say, a group of fair-haired men have no longer heads on the average, than a group of dark-haired men.

We can imitate this state of affairs exactly in animal experiments, and its meaning then becomes clear. Supposing we have two races of rabbits, a grey short-haired race like the wild rabbit, and a yellow long-haired race, and allow them to breed together at random, we shall find that after two or more generations there will be four kinds of rabbits, both long and short hair existing in the grey and yellow colours. But the proportion of long-haired rabbits will be no greater among the yellows than the greys. In technical language, we say that the length and colour of the hair are controlled by different genes. If we had several different mixed populations of rabbits, to some of which the yellow and long-haired race had contributed a larger proportion of ancestors than the rest, then in those populations there would naturally be more yellows, and more long-haired. And taking all these different populations together, there would be a correlation between yellow colour and long hair.

I mention these quite elementary facts because they have rather important consequences. It is generally thought that our Nordic ancestors had hereditary quali-

ties making for independence of spirit on the one hand, and a certain lack of imagination and tendency to alcoholism on the other. Now the genes responsible for such temperamental differences, if they exist, are doubtless inherited independently of those for head-shape or eye colour—probably independently of both. So even if we may expect more of these Nordic characteristics in the inhabitants of Grimsby than in those of Chester, we have no reason to expect them to be more strongly developed in a blue-eyed inhabitant of Grimsby than in a dark-eyed neighbour, provided the ancestors of both have lived there for some generations.

I have lately been reading several German books on the race question. One of them explains the well-known perfidy and untrustworthiness of the English by the fact that among a predominantly Nordic population Welsh characteristics constantly crop up. The facts are somewhat different. The present population of England is much more homogeneous than that of Germany, and much more nearly Nordic. Nowhere in England is there a population as short-headed as that of Bavaria. The present English population have skulls remarkably like those of the Iron Age inhabitants. We are a mixture, but the mixture is fairly intimate. However, because the differences between races depend on a finite number of genes, we do not get complete blending. On the contrary, physical characteristics of different races segregate out in the same family. One brother may be blue-eyed, another brown-eyed. And the same is true of psychological characters.

What, then, is the situation in England? We have a considerable diversity of innate temperaments, not only between different parts of the country, but between

neighbours in the same village. Throughout the country we have a bewildering diversity of soils, some suited for agriculture, others for cattle, others again for sheep or for woodland. We also have a long and indented coast-line, so that fishing and sea-borne commerce affected a large area of the country. Moreover, the small ships of the Middle Ages penetrated into the heart of England. Ships from the Hansa towns reached Cambridge.

Other countries, for example ancient Greece, had a similar diversity of occupations. But in England there are no physical obstacles to unity, such as mountain ranges or large rivers. The Norman conquest obliterated such old divisions as that between the East Angles and West Saxons. And feudalism was never so far developed as to break up the country into petty principalities as France, and still more Germany, was divided.

So much diversity within unity can, I think, account for certain fundamental traits in our national character. We respect our neighbours, and, on the whole, leave them alone. We are not polite to them. On the contrary, the English are one of the rudest of nations, at least superficially. But we respect their personalities sufficiently to allow a good deal of divergence in behaviour. For extreme examples of this divergence I recommend the reading of Miss Sitwell's *The English Eccentrics*, in which she chronicles the doings of men and women who would have been shut up as lunatics in many other countries, but achieved toleration in England.

Nowhere does this diversity show itself more than in our religious history. Wycliffe, the inspirer of Huss, was an English priest who contrived not to be burned until after he had died a natural death and been buried for some time. During the Reformation the Catholics burned

a certain number of Protestants, but this persecution was somewhat half-hearted. The Protestant governments never executed a single man or woman for catholicism, though they certainly killed a number of catholics on rather flimsy charges of high treason.

In the seventeenth and eighteenth centuries there was a bewildering outburst of Protestant sects, many of which last to this day. The most remarkable is probably the Quakers, or Society of Friends, which has contrived to survive for nearly three centuries as an organization without a priesthood, and to combine a profound mysticism and a real charity with considerable success in commerce. It has also reached extreme intellectual eminence. During the nineteenth century a Quaker was forty times as likely as a non-Quaker to be elected to the Royal Society.

I was once told by a continental acquaintance that England had produced no great men, except perhaps Cromwell. My friend was referring to the sphere of politics, for Shakespeare and Newton could hardly be denied a certain eminence in other spheres. It is certainly true that no public man has ever claimed to embody the national spirit as Napoleon did that of France, and as certain rulers claim to represent great peoples to-day. I do not think that we have even had a Bismarck.

But this is because the English are incapable of the unanimity which other nations display from time to time. We respect our own personalities enough to be very chary of surrendering them to a Leader.

Yet I think we have had as great statesmen as our neighbours on the continent. Let me take as an example one of our least conspicuous rulers, Sir Robert Walpole, who governed England for a generation during the

early eighteenth century. In former days execution, exile or imprisonment had been the lot of politicians who systematically opposed the government. Walpole was so strong a man, and felt himself so secure, that he contrived to avoid these measures, which are employed by the strong men of Europe to-day. He created that most remarkable of English political inventions, the constitutional opposition. It was a tyrant's slave* who said, or rather sang:

'O Engländer, Engländer, seid Ihr nicht Thoren,'

and similar sentiments are expressed to-day with regard to our toleration of opposition, and even of revolutionary movements. Walpole also kept his country from war, and immeasurably improved its health by introducing root crops. This enabled the English to get fresh meat during the winter, and thus banished scurvy, a deficiency disease associated with salt meat.

I regard the two-party system, much more than parliamentary representation or constitutional monarchy, as England's supreme and original contribution to political practice. It is not indispensable to parliamentary government, which has worked in France for sixty-five years with a quite different system. It may be that neither of these systems will continue to work during the coming period of economic change. But at least our system has lasted for two centuries, not wholly without success. It is illogical, but that is no drawback in a nation of empiricists.

The English have never respected logical coherence. They have never produced a great philosopher. The three greatest British philosophers were two Irishmen,

* In Mozart's *Entführung*.

Duns Scotus and Berkeley, and a Scotsman, Hume. The theology of the Church of England is an intellectually laughable compromise between the more coherent systems of Calvinism and Catholicism. But if, with Plato, Hegel and Marx, we believe that contradiction is inherent in all human thought, we may expect to find it in a religion which, if it is now dying, at least supported a robust morality for nearly four centuries.

I believe that our geology, our weather, and our racial mixture, have all served to warn us against too broad generalizations. Our great scientists have been content to bring intellectual order into some section of the world, rather than to build up a system of philosophy. But they did their individual pieces of work with extreme thoroughness. Darwin was content with putting forward a few quite simple ideas about evolution. He supported them by a mass of individual examples so overwhelming that they produced very general assent. More ambitious theorists such as Haeckel built on less solid foundations, and were more often wrong.

The French, on the other hand, are at their best when logical. If a Frenchman says 'Soyons logiques' you may listen to him. If he says 'Soyons réalistes' he will probably try to swindle you. The Englishman who claims to be logical is probably engaged in the familiar English trick of proving that his own conduct embodies the highest moral principles and yet, by a curious coincidence, will accrue to his own benefit. But when an Englishman says 'Let's get down to brass tacks', he is likely to produce a compromise which, if not logical, is at least equitable.

Let me illustrate my meaning from our politics. The German theorists who framed the Weimar constitution

thought that a body such as the Reichstag should be representative. If one-twentieth of the population held a certain political theory, one-twentieth of the deputies should hold it too. This may work in France, where the sentiment of national unity is far stronger than in England. It did not work in Germany, and would not in England.

Parliamentary government arose in England as an expedient to avoid civil war, and not as the result of any political theory. I am not so silly as to suppose that parliaments are infallible, or that majorities have a divine right to rule. I suggest that if a system of government has lasted for two centuries without revolution, this means that it has acted as a substitute for revolution, and thus made it unnecessary. It follows that a general election should lead to the same result as a revolution. And this is at least roughly true under the British system. There are several million liberals in England to-day who claim that they are unrepresented in parliament. True; but it is quite certain that a revolution, whether the socialists or the anti-socialists triumphed, would not put the liberals into power. Under proportional representation the liberals would have held the balance, and there would have been no chance of putting into practice either, on the one hand, socialism or, on the other, the protectionist policy of our present government. In Germany proportional representation led to a series of weak governments, and it is not surprising that the two anti-constitutional parties, the communist and the national-socialist, grew until one of them overthrew the constitution.

The Opposition, that most typical feature of English politics, takes some remarkable forms. There is a class

of Englishmen who have been described as 'the friends of every country but their own'. They are continually proclaiming the wickedness of the English Government, not only in internal affairs, but in the Empire, and in foreign policy. If they were not completely successful, they at least contrived to moderate the transports of English imperialism during the nineteenth century sufficiently to prevent a world coalition against their country. Even in time of war a considerable minority in England has either sided with the enemy, as during the Napoleonic and Boer wars, or at least aided the enemy indirectly, as did the conscientious objectors and their friends during the last great war. And perhaps an obscure realization that these men and women were highly characteristic of England saved them from very serious punishment.

Actually the existence of an official Opposition is an enormous source of strength in war-time. A British government might risk a minor war, such as the Boer war, which ran counter to the wishes of the Opposition. But it would never embark on a major war, a war in which defeat might be fatal, without being assured of Opposition support. Hence the anti-war and revolutionary movement is inevitably deprived of much of its strength, whereas in a totalitarian state it will crystallize round the illegal opposition.

The two-party system has a further great psychological advantage. The members of the cabinet have been in opposition together. They have got the habit of collaborating in the sham warfare of party politics. Except in the years immediately following a successful revolution there is no such bond between the ministers in a government either of a fascist state or such a country

as the Third French Republic or the pre-war German Empire.* My uncle, Lord Haldane, had great opportunities of studying the German Government before 1914. There he found the heads of several great departments of State, each magnificently organized, the Army, the Navy, the Foreign Office, the Treasury, with no such psychological bond between them, struggling to gain the ear of the Kaiser, intriguing against one another. Whereas the British Cabinet Ministers, though far less expert in the detailed knowledge required for government, were at least able to work together.

Our lack of logic has its bad side. We cling to many grossly obsolete institutions, such as the House of Lords. Our criminal law is shockingly behind that of many other countries, particularly Denmark. Some of our obsolete institutions may yet land us in disaster. Nevertheless our realism may help us. We are waiting to see how socialism works in Russia. If in the next generation the Soviet Union reaches anything like our own level of prosperity, the people of England, who have not been at all impressed by socialist theory, will be enormously impressed by socialist facts. In such a case it may yet be found that Marx was correct in his view that England was the only great European state in which socialism could possibly be established without revolution, though recent events have made this less likely.

I am only too well aware that in this brief sketch I have not even mentioned some of our most salient national characteristics, for example, our love of sport. I have said next to nothing about our literature or art,

* In the Soviet Union the Government are united by their common belief in a philosophical system. No English Government since the days of Elizabeth has been united on such a basis.

nor mentioned the fact that after two centuries of complete mediocrity English music is showing signs of renaissance. And perhaps I have not been sufficiently penitent for the philistinism which accompanied the sudden rise to prosperity and power of the middle class during the nineteenth century. This was not, however, specific to England.

I cannot close without speaking about the nations or races intimately associated with England, the Scots, Irish, Welsh, and Jews. Scotland is much less diverse geologically than England. Racially there is a sharp division between the Celtic Highlanders and the Lowlanders who are decidedly Nordic, and physically closer than the English to the Scandinavian type. The Scots are more logical than the English, and more left in their politics. But they lack to some extent the English realism and tolerance.

The union of Scotland with England was voluntary, and was, I believe, an example of the greatest thing that a man or a nation can do, namely, to die as an individual in the service of an idea. In the case of Scotland the idea was Protestantism. Scotland, unlike England, was largely moulded by a very great man, the calvinist reformer John Knox, who died in the sixteenth century, but whose spirit dominated Scotland for another three centuries. If there is ever a new John Knox he may perhaps be a communist. For the Scots do not love compromise.

England is full of Scots in high positions, but they seem to lack the flexibility of mind which is needed for dealing with human beings in unforeseen emergencies. It was not to a Scot, but to a Welshman, that England turned in the crisis of the great war.

I must confess to a prejudice in favour of the Welsh.

Many Englishmen do not like them. I find them delightful. They are emotional and quick-witted. Their gravest defect is perhaps that they require an audience. The Scot, with his belief in principles, can act alone, the Welshman with his deep sense for the emotions of his fellows, may seem lacking in principles. You will find these traits delineated in Mr. Keynes's brilliant portrait of Lloyd George at Versailles in *The Economic Consequences of the Peace*.

The Welsh were conquered by the English during the Middle Ages, and treated very cruelly. But by a fortunate accident the descendants of an English princess who had married a Welsh nobleman came to the throne as the Tudor dynasty, and ruled both countries with the greatest success. They imported a number of Welshmen into England, who played a part in the English renaissance. Moreover, the Reformation was effective in Wales, and indeed Welsh Protestantism is more extreme than English. Hence, although the Welsh are occasionally discontented with their position, they have never developed a strong anti-English feeling like the Irish.

Ireland, of course, represents one of England's greatest failures. The Irish were incompletely conquered during the Middle Ages, and never accepted Protestantism. North-eastern Ireland indeed became Protestant, largely through Scottish and English colonization. In the rest of Ireland Catholicism was persecuted during the seventeenth and eighteenth centuries. The English are not very good persecutors, and they did not succeed in making Ireland Protestant, but they did succeed in making themselves hated. And since the land was largely given to Protestant landlords there was a sound economic motive for the hatred.

Most of Ireland is now included in the self-governing Eire, and will, I hope, develop its own culture. However, there is a very large number of Irish Catholics in England and Scotland, and owing to their special religion and divided allegiance, they tend to remain a separate community, and not to be assimilated as Scots and Welsh are assimilated after a few generations, and as the French Huguenots who fled to England in the seventeenth century have been assimilated. Fortunately the Irish are popular as individuals in England, as they are of a cheery disposition and do not generally make fortunes at the expense of the English. But in Scotland there is a very strong feeling against the Irish immigrants, and a fascist movement in Scotland would almost certainly make use of it.

Finally, I come to the Jews. There is a fairly compact Jewish community in the Whitechapel district of London, and in a good many other towns. They have played a great part in finance, commerce, and politics. In the latter they have perhaps been most prominent as conservatives, the most striking figure being Disraeli, who was Prime Minister as Lord Beaconsfield. However, Jews are found in all our political parties except the fascists, who have not yet secured a seat in Parliament. They have not so far played any very great part in our intellectual life, though we have some Jewish scientists, philosophers, and novelists. Most Englishmen accept the Jew as a stimulating and rather picturesque element in our national diversity. However, in the last few years the fascists have launched an anti-semitic movement.

We have a few other foreign elements, for example Greeks, some of whom make rather good Englishmen, Italians, Cypriots, Indians, and negroes. India has had

a considerable influence on our culture. In particular the habit of taking a daily bath owes much to Indian example. But there has been much less intermarriage than in the case of the Dutch and the Javanese.

The English are not an intensely patriotic people. They are certainly less so than the French or than the Germans at the present* moment. This is largely because, living on an island, they have less reason than some others to be afraid of foreigners. Further, their allegiance is to some extent divided between England as such and the British Commonwealth of Nations as a whole. The interests of the two diverge appreciably. Thus the importation of New Zealand butter as well as Danish lowers the profits of the English farmer.

But if the Englishman is not patriotic, he is public-spirited. A surprisingly large amount of public work which in other countries is not done at all or done by the State, is done in England by voluntary effort. Most of the great hospitals, for example, are supported by voluntary subscription. So are many schools. The universities, though they get some State support, are largely maintained by private benefactors. Moreover, England is permeated with societies for more or less laudable objects. We have only two important parties, but thousands of societies with public objects. Some of these are wholly admirable, for example, the Royal National Lifeboat Society, which provides our excellent lifeboat service. Others, such as the Lord's Day Observance Society, which does its best to prevent the playing of games on Sunday, do not meet with such universal approval. The Englishman does not interfere with his neighbour as a private individual, but as a member of the Society for

Suppressing This or That he is perhaps rather prone to do so.

These voluntary associations certainly play a great part in English life. They furnish an excellent training for politics and public administration, and they must render a thorough study of the social structure of England exceedingly arduous.

Such are some of the qualities of my country. If you have known it for a long time you may love it or hate it as a whole. But one can hardly make this demand of a foreigner. I think it is much easier to love or hate a small country like Denmark or a large country strikingly different from all others, like the Soviet Union, than a microcosm like England. But come over, and you will find things to love and things to hate, as we English do.

BIOLOGY AND TOWN-PLANNING

THE Editor of the *Star* has asked me how, as a biologist, I should plan London. My first impulse was to refuse to write on the subject. For I certainly don't know enough about human biology to answer his question. Nor does anyone else. And sometimes it is worth while telling the world how little we know.

If a government asked me to plan the feeding of London's children I should take the job on. For I know where to go for figures as to what food they need, and what it costs. But there is no biological standard of housing to-day any more than there was a biological standard of diet fifty years ago.

We know a few basic facts about the effect of environment on health. Or rather we know what the position was in 1921. Since then our government has published very little on the question, because no one appears to be interested in it. Labour and Liberal men and women find it just as boring as Tories, because what little knowledge we have is based on statistics.

We know that country life is far healthier than town life, and that poverty is not a serious cause of death in the country, since farm labourers live as long as their employers, except for a slightly greater infantile death-rate. We know that in the towns the poor die very much quicker than the rich. And most of the occupations which are healthy for town dwellers, such as driving vehicles, involve a good deal of exposure to fresh air.

We don't know how much of the high death-rate of the

urban poor is due to overcrowding. Certainly not all. Some is due to the fact that most of the people who can't afford a proper house can't afford proper food either.

And there are more sorts of overcrowding than one. Mr. Smith lives in a nice roomy house at Edgware, but spends an hour a day in grossly overcrowded tube trains. He might be healthier if he lived in a much smaller house in central London, but walked to and from his work. Mr. Jones has a roomy house, and walks to his work, but he goes to a stuffy cinema every evening, except when he attends rather crowded political meetings where I and other speakers spray him with germs from our throats. Should we plan to avoid these varieties of overcrowding, and would anyone thank us if we did?

I pass over the more obvious aspects of planning, such as broad straight roads, zoning of separate residential and factory areas, parking places for motor vehicles, and so on. Even with considerably better roads, and staggering of hours of work, we should still have gross overcrowding of transport if the present tendency to work in the centre of London and to live on its edge, continues.

So my first task would be to try to make central London a place fit to live in, with open spaces for children to play, and as much sunlight as possible for everyone. We can only make room for the present population if we build taller buildings. These buildings would take the form of large blocks of flats. The individual house in a large town is a luxury. Only millionaires can afford one in central New York, and as millionaires and planning don't go together, no one would be able to afford one in a planned London.

Unless the planned London was part of a planned world, every large building would have a bomb-proof

basement. Impracticable, did you say? Well, planning is going on in Barcelona. Some of the largest of the bomb-proof shelters now * being built there are to be the basements of schools when the war is over. The Catalans have had too many schools hit to take any chances in future.

There would be a minimum standard of crowding, and a maximum, to be gradually approached for all, of a small bedroom with its own shower-bath and lavatory, for each unmarried person over three years old. The number of living-rooms per family would rise from a minimum of two. Cooking would be largely communal, but I see no reason to discourage meals in the home.

One serious problem arises in the planning of large blocks. If every room is to have an outlook onto a street or garden the buildings would have to be so tall and narrow as to keep most of the sun from the ground level. I do not believe in the need of direct sunlight for bedrooms. And fresh air is somewhat of a fetish. If enough people sleep in one room it must certainly have its windows open if they are not to infect one another. But ventilation with purified and conditioned air is probably as healthy, and certainly cleaner, than ventilation by open windows. So in the interest of light for London as a whole I would be willing to have many bedrooms, but no sitting-rooms, opening on narrow walls, and artificially lit.

Every roof would be a garden, and about one block in four would be an open space. Smoky fires and steam locomotives would be forbidden, and buildings faced, so far as possible, in white or bright colours. Even so we should have enough dull and rainy days to make provision for indoor physical recreation necessary. Here I should be inclined to copy the Peckham health centre on

a very large scale. This really admirable institution provides swimming and other exercise for its members, and also facilities for a medical examination from time to time even when they are well, and whenever they are ill.

London would have a thousand of these health centres instead of one, and the emphasis in the medical profession would pass from the cure of disease to the positive encouragement of health. The general public would be far more willing to undergo an annual medical inspection if it were conducted in a building which was also a clubhouse.

Among the most overcrowded places are public-houses. This is partly because there are not enough of them in some parts of London, but mainly because there is nowhere else where a working man can go of an evening to talk. My plan would include a great variety of alternatives. A group of men or women would find it easy to hire anything from a small room to a large hall for any communal purpose, music, chess, politics, drama, or simply conversation.

Some would serve a double purpose. For example, if most of the young married women went to work, as they would in a planned London, we should need plenty of crèches in which they could dump their babies during the day. These could be used by workers for recreation in the evening.

It would be up to planners to break the monotony of a planned city in such ways as this. There would be other planned recreations on a larger scale. I would have at least half a dozen zoos in London, and several botanic gardens besides Kew. They would be part of a general scheme to get Londoners to think in terms of life rather than mechanism.

A very important part of the plan would be experiment. We know something of the effect of hot wet air in the factory on human health from its killing effect in the Lancashire cotton mills. We knew very little about the healthiest temperature in the home. Yet if climate out of doors affects health, so should climate indoors. Different buildings would have their air supply at different temperatures and the effects noted. The health of people living on the north and south sides of a building would be compared. Only so would we get the needed data for a further step in planning.

Would this make us a nation of valetudinarians? I don't think so. I am not a miser because I look at my bank balance once a month. In a socialist community once a general level of comfort was reached, a non-competitive struggle for health might well supersede the competitive struggle for wealth.

And planning implies socialism. Ordinary capitalism does not plan. Fascism at best plans in a one-sided way. Berliners are building a planned city with a planless food supply. But socialism will only succeed if socialists realize that to make an urban population really healthy is a scientific problem, and above all a problem which cannot be solved on the basis of our existing knowledge.

UNIVERSITY OF CHICAGO
SERIALS ACQUISITION
JAN 19 1964

IS SCIENCE ADVANCING?

THE British Association for the Advancement of Science is meeting in Cambridge, and the Editor of the *Sunday Graphic* has asked me whether science is still advancing. A generation ago everyone except a few cranks would have said 'Yes' without hesitation. But now people doubt it for two reasons. The science which we know is not being applied. What is the good of applying science to growing potatoes if you are fined for growing too many, as a Dorset farmer was recently fined? New industrial processes are not applied because they would involve scrapping costly plant. This is bound to happen when monopolism is introduced into industry by trusts, and into agriculture by marketing boards. Whoever is to blame for this state of affairs, it is not the scientist.

The other reason is that the public has lost touch with the progress of science. This is partly the fault of scientists for not writing in a language that people can understand, and partly the fault of the public for being more interested in theories than facts. No theory lasts for ever. Forty years ago most physicists believed that material bodies moved through a fixed ether which transmitted light. On the basis of this theory radio communication was invented. Then Einstein showed that there was no fixed ether. But the radio stations did not stop working because the theory on which they are based had broken down. On the contrary, they work a little better because we have a better theory.

So in what follows I am going to describe some recent

advances in science which deal with facts, not theories. That is to say, even if future generations describe them in different words, they will have to recognize their existence. I do not much care whether light consists of waves or particles provided I can control it so as to use a microscope, a telescope, or a searchlight. I am interested in science not as a set of pretty theories, but as a means of controlling nature.

Let us begin with astronomy. For every hundred people who have heard discussions about the expanding universe (whatever that means) I doubt if one has read of the discovery made by Jansky, an American radio expert. He finds that there is a source of radio waves of about 15 metres length in the sky. These waves do not come from the sun or any of its planets, but from the constellation Sagittarius, which we can see in the south on summer evenings. Men have studied the heavens with their eyes for thousands of years, and with telescopes for hundreds. Now at last we have a new instrument, and no one can yet guess what invisible things it may disclose.

Another set of radio experts, led by Professor Appleton, is investigating invisible things in our own atmosphere. Everyone knows that the waves from broadcasting stations are reflected down by layers in the upper air which are opaque to them, but let light through. A careful study of the reflection of signals sent out from King's College, London, and recorded at Hampstead, shows that below the lowest layer there are separate clouds invisible to the eye, but reflecting short waves. They have not yet been studied for long enough to know whether they will help us to predict weather changes, but this is quite possible.

To come still lower down, until five years ago people

thought that a lightning flash was something simple and almost instantaneous. The Professory Boys invented a camera with a moving lens which showed that a lightning flash is about as complicated as a high jump seen on a slow-motion picture. It begins in the cloud, and comes down in a series of steps each about fifty yards long. At the end of each step there is a pause, and often a change of direction. When it gets to the ground, another much brighter flash starts moving upwards to the cloud. The whole thing is over in about one ten-thousandth of a second. But very often another pair of flashes along the same path start about a hundredth of a second later, and as many as twenty pairs may move along the same track. This knowledge is already being applied to protect the grid of electric power transmission lines from the effects of lightning.

Geography is a nearly complete science except for the Arctic Ocean and the Antarctic continent. There are no great new rivers and few new mountains to be found. But we have much to learn about the sea bottom. Biologists had long known that the animals and plants of Madagascar and India resemble one another, and therefore believed that they were connected by land in the past. The geologists were more doubtful until 1936, when a British ship making deep-sea soundings found a range of submarine mountains extending across the Indian Ocean, which may be the remains of a land which once united Madagascar to India.

Though we know a lot about the soil and rocks in most parts of the earth, until last year we knew nothing about the ocean-bed, except the mud in the top inch of it. Then an American scientist called Piggott invented a gun which is lowered to the bottom of the sea, shoots a brass tube

down, and finally picks up a sample of the ocean-bed like the cores of rock which are removed when an oil well is being drilled. Samples of mud from the bottom of the Atlantic showed records of the past. The mud is largely composed of the shells of tiny animals like those found in chalk. But a few inches below the surface they are mixed with volcanic dust, perhaps from Iceland. Then come shells of animals now only found in the Arctic Ocean, but which lived in the Atlantic during the last Ice Age. In fact, the sea bottom is a record of the weather for millions of years back, except where currents are strong enough to drift the mud. One part of the Indian Ocean is paved with lumps of rock containing manganese and other valuable metals. And at some future date it may pay to dredge these up from a depth of two or three miles rather than to mine for them.

These are some examples of progress in our knowledge of large-scale things during the last five years. Now let us turn to smaller things. Not atoms, though. We have found out plenty about atoms in the last five years. And it is easy to give a theoretical account of them, but it would take this whole article to describe a small fraction of the facts, which cannot be altered, whereas the theory is bound to be. Let us start then with chemistry, which takes the atom for granted. The biggest advances here are hard to explain in the space at my disposal. But there are plenty of practical applications too. One of the greatest has been the development of plastics, that is to say synthetic resins which can be moulded into any form. These have now been made so transparent that they will replace glass for many purposes. A lens of resin costs far less than a glass one, and is less brittle. But it is more easily scratched, and softens in an ordinary oven. In

ten years I have no doubt that plastic lenses will be used instead of glass for most spectacles and field-glasses, though glass will hold its own for telescopes and microscopes.

The achievements of medical chemistry are still greater. Benzedrine is one of the most amazing drugs ever produced. It keeps one awake when fatigued, and speeds up various activities without causing mental confusion or physical clumsiness. It does not create addiction. However, like all drugs with any real effect, it is dangerous, for one thing because it raises the blood pressure. It is quite possible that it may have an unforeseen effect in abolishing the examination system. A number of London students got first classes on benzedrine this year, and when this becomes common and a few dozen have killed themselves we professors will probably have to devise some better tests of ability.

Another valuable but dangerous group of drugs are prontosil and other derivatives of sulphanilamide. They cure certain kinds of abscesses, and infections such as puerperal fever and gonorrhoea in a few days. But they are dangerous. They often make the patient ill and sometimes kill him. No doubt experience will make them a good deal safer. Some drugs of this kind have been tried on the cancers which are common in old mice. And some of them seem to have been cured. However, it is still too early to predict whether they will be any use against human cancer.

The physiologists have probably found out how a nerve stimulates a muscle to contract. At any rate they have got near enough to the truth to be able to treat those kinds of paralysis in which this particular link in the chain between brain and muscle has broken down.

Unfortunately the effects of a single injection of the curative drugs only lasts for a few hours. But the time will probably be extended, and meanwhile the patients can at least move their limbs normally for some hours daily.

A number of diseases such as smallpox, measles, and infantile paralysis are caused by agents far too small to be seen by the microscope. Stanley in New York prepared the first of these in a pure state, and Bawden, Bernal and Pirie have investigated a number of them in England. In some respects they behave like living things, in others like inert chemicals, and they actually serve to bridge the gap between the living and the non-living, and to throw light on the problem of life's origin.

Other gaps in the story of evolution have been bridged by a study of fossils. The great South African palaeontologist Broom has found intermediates both between reptiles and mammals, and between monkeys and men. Stensio in Norway has similarly bridged the gap between fish and amphibians such as the newt. One great difficulty in Darwinism remained. A greyhound and a bulldog look more different than a horse and a donkey. But they will breed together freely, and the hybrids, unlike mules, are fertile. So critics of Darwinism thought that only varieties, but not species, could be produced artificially. However, Koshevnikov in the Soviet Union has now produced a new species of fly. It breeds true, but when crossed with the species from which it is derived it gives practically no offspring (to be accurate, one for every thirteen thousand produced by matings within the old species). Unfortunately it would take several centuries to produce a new species of dog by the same method. But there is no reasonable doubt that it could be done.

These are a few samples of the progress of science in the last five years. Some people will say that they are trivial, that there are no scientists to-day of the calibre of Harvey, Faraday, or Rutherford, let alone Newton and Darwin. I do not agree. But the work of great men is so novel that it takes a generation to assess its value, and it cannot be summarized in a single paragraph. So I have not even mentioned half a dozen men, of whom posterity will perhaps regard three as men of outstanding genius, and the other three as hopelessly muddle-headed. I have my own views, but I may be wrong.

Scientific progress could be much quicker. But if young chemists cannot get jobs for research on drugs, but can readily get them for secret work for military or industrial purposes, this fact is bound to slow it down. It is up to the people to see that research is concentrated on branches of science which are likely to be useful to the community. And if this is not done they cannot justly blame the scientists if science does not advance as quickly as it might.

WHY I AM A MATERIALIST

WHEN I say that I am a materialist I mean that I believe in the following statements:

1. Events occur which are not perceived by any mind.
2. There were unperceived events before there were any minds.

And I also believe, though this is not a necessary logical deduction from the former two, that:

3. When a man has died he is dead.

Further, I think that it is desirable that other people should believe these statements. I do not mean that I believe that the universe is a machine, nor that I am a machine; nor yet that consciousness does not exist, or has a lesser reality (whatever that means) than matter. When I say 'I believe' I do not mean the word in the sense in which a fervent Christian uses it concerning the Virgin Mary, Pontius Pilate, and others who figure in the creeds. I mean it in the ordinary sense, in which, for example, I believe that dinner will be waiting when I go home, though of course the cook may go on strike or the chimney may catch fire. That is to say I act, and propose to act, on the basis that materialism is true. But I am prepared to consider evidence to the contrary. And I certainly don't get shocked or angry if someone criticizes or doubts the truth of materialism.

Now the word 'materialism' is used, particularly in controversy, to imply a belief that a good dinner is better than a good deed. In fact, a materialist is supposed to be a man who has, or does his best to have, large meals, a large

mistress, a large bank balance, a large motor-car, and so on. It is not obvious why this should be so. Other people's meals are as material as mine, and a bank balance is not something tangible, like a cellar full of gold and jewels.

In practice I have found that professed materialists are generally less selfish than professed idealists. For idealism is a remarkably useful device to enable us to bear other people's ills, and particularly their poverty. It is easy to persuade ourselves that the poor have various spiritual blessings. But it is not so easy, when one's own affairs are concerned, to avoid the attitude of the idealist of whom it was written:

There was a faith-healer of Deal
Who said: 'Although pain isn't real,
When I sit on a pin and it punctures my skin
I dislike what I fancy I feel.'

I do not of course deny that some idealists are excellent people, and some materialists coarse and selfish. But on the whole I think the contrary is true, for reasons which will appear later.

Fifteen years ago I was a materialist in practice, but not in theory. I treated myself as a material system. We all do this to some extent. When we want to go somewhere we get into a train or bus, confident that on the one hand we shall not be able to propel ourselves so rapidly through space by the mere exercise of our wills, nor on the other that the vehicle will find any more difficulty in moving us than if we were a sack of potatoes. However, though we all have considerable faith in the applicability to ourselves of the laws of physics, our faith does not apply to chemistry. We should be willing to trust our weight to a rope which had been tested to stand double our weight; but we should mostly hesitate to drink half

the fatal dose of a poison. Rightly too in some cases, for poisons in sub-lethal doses may do a good deal of harm. But not by any means always. Some poisons, such as carbon monoxide, are completely harmless in half the lethal quantity.

I applied the laws of chemistry to myself. For example, I said: 'If a dog is given hydrochloric acid to drink (diluted of course so as not to injure its stomach) it excretes part of the acid combined with ammonia as ammonium chloride. Now men work in a similar way to dogs, and both are systems of partially reversible chemical reactions. So if I eat ammonium chloride I shall become more acid.' This did in fact happen. I was quite correct in my reasoning, or at any rate it led to a correct result.

However, although I was a materialist in the laboratory, I was a rather vague sort of idealist outside, for the following reason. I had learned that matter had certain properties. It consisted of atoms which united in particular patterns. They moved in definite paths under given forces, and so on. My belief in these theories was not a matter of mere docility either. I had tested them and risked my life on their substantial accuracy. Clearly, if matter had the properties attributed to it by physicists and chemists, something more was needed to account for living organisms. And it was far harder to account for mind. As a believer in evolution I had to reject such theories as T. H. Huxley's epi-phenomenalism, according to which mind is a secondary consequence of a small class of material events (namely, those which go on inside our heads), but does not influence them. Apart from my very strong belief that I can act, the evolution of something as complicated as my mind, yet absolutely functionless, seemed most unlikely. Not that functionless organs

are never evolved. On the contrary, it is probable that most organs are evolved in a rudimentary form before they develop a function. And I have not enough faith in the theories of Paley and his like to believe that every organ—for example, a cock's comb, a pigeon's cere, or a cassowary's wattle—has a function. However, I cannot believe that a system so complicated, and within its limitations so efficient, as the human mind could have evolved if it were functionless.

Nor did I see how, on a materialist basis, knowledge or thought was possible. The light which reaches my eyes causes nervous impulses in about half a million fibres running to my brain, and there gives rise to sensation. But how can the sensation be anything like a reality composed of atoms? And even if it is so, what guarantee have I that my thoughts are logical? They depend on physical and chemical processes going on in my brain, and doubtless obey physical and chemical laws, if materialism is true. But if so I have no reason for thinking that it is true. So I was compelled, rather reluctantly, to fall back on some kind of idealistic explanation, according to which mind (or something like mind) was prior to matter, and what we call matter was really of the nature of mind, or at least of sensation. I was, however, too painfully conscious of the weakness in every idealistic philosophy to embrace any of them, and I was quite aware that in practice I often acted as a materialist.

The books which solved my difficulties were Frederick Engels' *Feuerbach* and *Anti-Dühring*, and later on V. I. Lenin's *Materialism and Empirio-criticism*. But the actual progress of scientific research in the last fifteen years also helped me enormously. None of the books which I have mentioned is easy if one has been brought up in the

academic tradition which goes back to Plato and Aristotle. This is partly because they apply scientific method not merely to philosophy, but to philosophers. They are not only concerned with showing that their authors are right and their opponents wrong, but with explaining why, under particular social conditions, such and such theories are likely to gain wide acceptance. Hence, unless one accepts their political and economic theory, one is not likely to agree with their views concerning nature and knowledge, though it is only with the latter that I am concerned in these pages.

Engels and Lenin were firm materialists—that is to say, they believed that matter existed before mind, and that our minds reflect nature, and reflect it truly up to a point. But they absolutely rejected the current scientific theories of their day as complete or even satisfactory accounts of nature.

The sole property of matter [wrote Lenin], with whose recognition materialism is vitally connected, is the property of being objective reality, of existing outside of our cognition. . . . The recognition of immutable elements, the immutable substance of things, is not materialism, but metaphysical, anti-dialectical materialism. . . . It is of course totally absurd that materialism should . . . adhere to a mechanistic world-picture of matter and not an electro-magnetic or some immeasurably more complicated one.

Writing of the physics of his own day, he said: 'Dialectical materialism insists on the temporary, relative, approximate character of all these milestones on the road of knowledge of nature.'

Nature is in a state of perpetual flux—in fact, it consists of processes, not things. Even an electron is inexhaustible—that is to say, we can never give a complete

description of it. We professors are always trying to give such a complete description, so that we can deduce all natural happenings from a few general principles. These attempts are successful up to a point, but we always find that nature is richer than we had thought. And the newly-discovered properties of things appear to us as contradictions. Thus at the present moment both light and matter are found to have two sets of properties—one set resembling those of particles, and another set resembling those of waves. According to Engels and Lenin, things really embody a union of opposites, whose struggle makes them unstable and results in their development into something else. When we find 'internal contradictions' in our conceptions about things our minds are mirroring nature.

But these internal contradictions do not mean that nature is irrational. They mean that it is unstable. Our brains are finite. Nature is probably infinite, certainly too large for us to take in. So our account of any material phenomenon is a simplification. We naturally think of things as neatly rounded off, and therefore tend to exaggerate their stability. However, the more we study nature the more we find that what is apparently stable turns out to be the battlefield of opposing tendencies. The continents are the field of a struggle between erosion, which tends to flatten them, and folding and vulcanizing, which build mountains. For this reason they have a history. Animals and plants are never completely adapted to their environment, as Paley thought, and as they presumably would have been had they been made by an all-wise and all-powerful creator. On the contrary, they evolve just because they are imperfect. The same principle holds for human societies.

One of the materialist's greatest difficulties used to be

perception. If the world consists of self-contained objects isolated from one another in space, how can any sort of image of it be formed in our brains? There is no hollow space in our heads where a puppet representation of the external world could be set up. Sound is the only feature of the external world about whose representation in our brain we know much. If we place an electrode on the auditory part of a cat's cerebral cortex and another somewhere else on its body, then in favourable circumstances if we amplify the current between them and pass it through a loud-speaker we actually hear sounds which the cat is hearing, or would hear were it fully conscious. The same experiment is quite possible with a conscious human brain, though I don't think it has yet been done.

This means that the ear and the auditory nerve serve to set up electrical disturbances in one part of the brain with the same periods as the disturbances in air which we perceive as sound. In this case, then, there is an actual imaging of the external reality. But how can anything of this kind take place with a solid object seen or felt? The physical discoveries of the last decade have shown that ordinary material objects, from electrons upwards, can be regarded as periodic disturbances. Certainly the rhythm is very much faster than that of sound, and could not possibly be copied in the brain. But some kind of rhythmical changes in the brain, though very much slower than those which they mirror, would be copies of at least one aspect of matter.

The physicists tell us that the frequency of the vibrations associated with a particle are proportional to its mass, and the physiologists, in studying the impulses in a nerve fibre from an end organ responsible for our touch or pressure sense, find that the frequency of the impulses

increases with the stimulus, though not in exact proportion. We do not yet know in any detail what happens in the brain when we feel pressure, but it is likely that a similar law holds good.

We are only on the very fringe of the necessary investigations, but it is becoming daily more plausible that our minds are physical realities acted on by the rest of the world and reacting on it. Our minds are processes which occur in our brains. Until recently it was quite impossible to see how the processes going on in thousands of millions of cells could possibly form a unity such as we find in our consciousnesses. We are now, however, discovering both in atoms and molecules properties of a system as a whole which cannot be located at any particular place in it. There is nothing in any way mystical about these properties. They can be very precisely measured and calculated. They are expressions of the fact that the various constituents of nature are much less isolated than was at one time thought.

The difficulties about truth are complicated by the fact that we use the word for at least three very different relations. We may mean that a perception or idea in a mind is true if it corresponds to an external reality. If the relation between the two is one of likeness it can never be complete, but it may be true enough for a particular purpose. We may mean that a physical copy or image is like its original. Or we may mean that a statement is true. This statement may be in words or other symbols, and logic is largely concerned with the truth of statements. Their truth or otherwise depends on the meaning of the symbols. This is a social matter. A statement is true only as long as someone understands it. After that it is meaningless. 'Iron is heavier than water' will be true as long

as someone understands English, even if he is only an antiquarian. After that it will be gibberish like 'Pung twet maboroohoo', which for all I know meant something to the men who built Stonehenge, but is neither true nor untrue to-day.

Of course the philosophers say that a symbolic statement stands for a mental reality called a judgment, which is independent of language. I think this is extremely doubtful. On the contrary, it seems much more likely that language began with words or phrases whose English equivalents would be 'Come here', 'Wolf!', 'Heave-ho,' 'Darling!', and so on, which are not statements, and neither true nor false. And one can certainly think without making statements or judgments, as when one remembers the plan of a town and picks out the quickest route, or imagines what an acquaintance will do in given circumstances.

The great advantage of the theory that judgments are anything but sentences repeated in our heads is that it gives philosophers a chance to theorize about thought without investigating the physiology of the brain. This enables them to tell us a lot about truth, but very little about how we get to know it or how we act on it. If we take the view that a statement is true in so far as it calls up mental images which correspond to reality, and useful in so far as it cites actions appropriate to the real situation, we have got away from metaphysics, and are up against problems concerning the action of the brain, the history of language, and how we learn language as children, which cannot be solved by pure thought, but only by studying the real world.

For such reasons as these I find materialism intellectually satisfactory. I also think it is useful because it leads to

actions of which I approve. Mankind is up against a very difficult situation. We have dealt with a great mass of problems in the past by scientific thinking—that is to say, materialistic thinking. We try to solve our political problems by appeal to eternal values. But if we start thinking materialistically about these 'eternal values' we find that they are social phenomena which have come into being in the last few thousand years, because men gave up hunting and took to husbandry, agriculture, and handicraft. So society became a great deal more complicated, and 'eternal values' are part of the apparatus by which it has been kept going. In particular they are very useful to those who are in comfortable situations at present, and would like the present state of things, with a few minor modifications, to be eternal.

Materialistic thinking in the past has been revolutionary in its effects. It has built up natural science and undermined religion. The same process is going on to-day. We have to realize that our current ideas about society are mostly very like our ancestors' ideas about the universe four hundred years ago—irrational traditions which stifle progress in the interests of a small minority. These ideas are being transformed by materialistic thinking about history as our ancestors' ideas were transformed by materialistic thinking about nature. The consequence will no doubt be revolutionary, as it was in the past. This would perhaps be deplorable if our society were working well. But it is working very badly. So we are probably going to have an uncomfortable time in the immediate future, whatever happens. And as I want a rational society to come out of our present troubles I am not only a materialist myself, but I do what I can to make other people materialists.

WHAT IS RELIGIOUS LIBERTY?

ALL Rationalists, and most religionists in Britain, claim to believe in religious liberty. And I suppose they would all agree that no one should be killed, imprisoned, or even fined for his or her religious opinions. But how much farther are they willing to go? Thomas Paine said that 'liberty consists in the right to do whatever is not contrary to the rights of others'.

Yes; but what are other people's rights? Do they include a right to beat one's child if he does not go to church? Or have children a right to choose their own religion? Do they include a right to wake up one's neighbour in the morning because one is about to hold a religious ceremony? Or would I be right to climb the church steeple and cut the bell-ropes? Do they include a right to use endowments to propagate a doctrine when the property was originally intended for the support of a very different doctrine? Do they include a right to use the streets for processions? Or should streets be reserved for traffic?

Perhaps we shall get a clearer view on these questions if we consider the conditions which prevail in the Republic of Krassnia, whose people mostly claim that they enjoy very full religious freedom, though others take the contrary view. The official doctrine of Krassnia is Dialectical Materialism. In the past it was Mechanistic Materialism, and some traces of this survive. Thus when a new President is installed, as occurred last year, he is formally oiled by the Chief Materialist. This was origin-

ally intended to signify that he was a machine, but the meaning is now often forgotten, and it is generally admitted that the interest of the ceremony is mainly archaeological.

However that may be, Dialectical Materialism is closely connected with the State. The President and the Minister of Justice must be Dialectical Materialists, though the Chief Commissar need not be. But he would not hold his position for long if he were so rash as to attack that theory openly; and, whatever his views may be, he usually finds it expedient to attend from time to time one of the rather tedious lectures on that topic which are given every sixth day in special lecture-halls.

Again, twenty-five men chosen from the ranks of the lecturers are appointed by the Government to the Upper House to represent Dialectical Materialism. They serve a valuable purpose in persuading the people that the Government's measures conform to that doctrine on the whole, and they do this all the more effectually because they frequently criticize the Government in matters of detail, and lament that the country is falling away from materialism.

The huge endowments of Dialectical Materialism do not come directly out of the national revenue; and this gives the Government an excellent excuse for claiming religious impartiality. During the last seventy years the State has drawn little distinction between different more or less materialistic doctrines. There are methodistic materialists, dogmatic atheists, sceptical atheists, and many more sects. The present Chief Commissar is a Nullitarian atheist; and because of this many Krassnians honestly believe that they enjoy complete toleration.

Actually all forms of atheism and materialism are in-

directly subsidized by the State, since buildings used for the propagation of these doctrines enjoy immunity from various forms of taxation. Buildings used for religious purposes are no more highly taxed than any others, but any tenant who holds a religious service may be ejected without notice. It is only fair to say that this law is rarely enforced.

Education is often stated to be impartial; most elementary schools are paid for by the State. In these a certain amount of formal instruction in materialism is given weekly. Children whose parents object are not compelled to attend. However, a large number of schools are owned by various irreligious organizations, but subsidized by the State. Here the anti-religious propaganda is a good deal more systematic, and the teachers must at least pretend to be good materialists. There are no specifically religious schools, though occasionally religious propaganda is put over at special classes on the sixth day in State schools; but this always leads to trouble, and sometimes to the dismissal of teachers.

Many of the secondary schools and universities are specifically materialistic. Indeed, in the 'best' of the schools the children are compelled to attend lectures on materialism twice daily. A Christian friend in Krassnia has told me that, after six years of this propaganda, materialism becomes absolutely meaningless to the children, and they are often converted to Christianity without difficulty. This may be true; but there is another side to the question. Even the converts to Christianity are so saturated with materialistic principles that they still follow them unconsciously even when they have rejected them consciously.

And here literary tradition plays a considerable part.

There is no doubt that the translations of Lucretius, Diderot, and Engels are among the finest literature in the Krassnian language—some say they are better than the originals. These are so assiduously taught that their ideas are part of the common stock. Indeed, it is not uncommon to hear a prominent Christian quoting these works in a public speech.

Just as materialism is bound up with their ideas on all topics, so it is inextricably mingled with their public life. To take a simple example, the National Anthem begins—

There is no God in Krassnia.

This song is sung, or its tune played, not merely at official ceremonies, but at the close of stage plays and film shows. On these occasions the whole audience is accustomed to sit down, and the men to put their hats on as a token of reverence. Christians who objected to this form of blasphemy have often been assaulted, though of late years on the ground that their action was unpatriotic rather than anti-materialistic. Judges have held that such assaults were justified, as a failure to sit down was insulting behaviour.

The radio is, of course, controlled by materialists, and brief discourses on materialism are given twice daily, while much longer and duller lectures occupy much of the programme on the sixth day. A few Christians have in the past been allowed to give a rather diluted account of their religious tenets, but this led to so many protests from materialistic listeners that such propaganda has now ceased. At no time have the most important religious bodies, the Religious Press Association and the National Salvation Society, been permitted to use the radio; and there was a storm of protest when the former rented a

foreign radio station for an hour, though the discourse was of a most moderate character, and care was taken not to hurt the feelings of materialists.

Unofficial Christian propaganda is not forbidden, but it is discouraged in every possible way. Only one daily newspaper, the *Daily Warner*, has a fundamentally Christian outlook; but even this is kept in the background owing to the fear of offending materialists who sympathize with its opinions on political and economic matters. It is a remarkable fact that the vast majority of Christians in Krassnia prefer to buy a materialist newspaper which agrees with their political views rather than a Christian newspaper which does not do so. The result is not only that the *Daily Warner* is run at a loss, but that it is far less openly Christian than would otherwise be the case.

An International Christian Congress is to be held in Krassnia this year. A number of deputies attempted to stop it. They claimed that it would lead to violence by the indignant proletariat, and that it would be used as a vehicle for Fascist propaganda. However, this Congress, though officially discouraged, has not been forbidden. It will be interesting to see whether it will lead to any acts of violence; but the odds are at present against this.

The only sphere in Krassnia where religion is actually persecuted is the armed forces. On joining the army every recruit is asked his irreligious opinions. The majority register as Dialectical or Mechanistic Materialists, except in North Krassnia, where Hylozoism is in favour. However, Positivism, Agnosticism, and several other opinions have lately been legalized. But no soldier may register as a member of any religious organization. And if he is killed in battle a wooden O, to symbolize annihilation

after death, is always placed over his grave. On the sixth day every soldier is compelled to attend a lecture on the tenets of his particular brand of irreligion; refusal to do so is punished as a breach of discipline by imprisonment. It is only fair to say that no Christian soldier in Krassnia has so far, like St. George, been martyred for refusal to obey such an order; but many have been punished in minor ways. And, although the State does not formally subsidize materialism, it pays some hundreds of materialistic lecturers to bore its soldiers, sailors, and airmen.

The perspicacious reader will by now have noticed that the conditions described in Krassnia are exactly those in Britain to-day, substituting 'Dialectical Materialism' for 'Anglicanism', 'Mechanistic Materialism' for 'Catholicism', the *Daily Warner* for the *Daily Worker*, and so on. If he compares the conditions prevailing in Krassnia with those which prevail in the Soviet Union to-day, he will find that religion is freer in the Soviet Union than in Krassnia in some respects, and less free in others. Thus in the Red Army it was recently found that a large fraction of the soldiers were theists, whereas in the army of Krassnia atheism is compulsory, and in the British army every soldier is compelled to be a Christian or a Jew. On the other hand, few religious books are published in the Soviet Union, though some are. For example, a translation of Cardinal Newman's *Apologia pro vita sua* was recently printed. They are permitted in Krassnia provided their style is not of such an honest and straightforward character as to come under the blasphemy law. As against this, although atheism and materialism are associated with the State in the Soviet Union, they are not rammed down the throats of the public as is materialism in Krassnia or religion in England. The worthy

Comrade Yaroslavski, President of the League of Militant Atheists, enjoys a position very inferior to that of the Chief Materialist in Krassnia, or the Archbishop of Canterbury in England. If formal religious instruction of children is forbidden, I have yet to learn that there is any compulsory instruction in irreligion. And certainly they are not compelled to assent to any philosophical doctrines, as many British children are forced to recite the Catechism and the Creeds.

To sum up, there is about as much religious freedom in the Soviet Union as in Great Britain. I should like to see a little more in each. I do not know of any legislative step in that direction taken during the last ten years in Britain which is comparable with the enfranchisement of priests in the Soviet Union in 1937. Of course, in so far as they are followers of Engels, Communists are definitely enjoined not to use the police 'to attack religion and thereby help it to martyrdom and a prolonged lease of life', to quote from the last chapter of *Anti-Dühring*. This does not mean that they should not argue against religion or suppress organizations which use religious forms for political ends.

It seems to me that most discussions by Rationalists concerning religious liberty have been far too abstract. In a laudable but futile attempt to be impartial they have neglected the fact that many forms of religion are absolutely opposed to liberty. If a priest terrorizes parents by threats of hell-fire into forcing their children to go through the motions of religious observance, this is a strange sort of freedom. On the other hand, it is right and reasonable that children should be taught something, in school about the prevailing forms of religious belief or unbelief in their own country, and any attempt by their

parents to prevent this is, I think, short-sighted, and likely to have an effect opposite to that intended—at least, in the case of intelligent children.

Our notions of freedom are apt to be dominated by two ideas, neither of which is up to date—the idea that the patriarchal family is natural and normal, and that large sums of money can be left for the propagation of opinions without harm to freedom. Actually the patriarchal family is only one out of many types. To many primitive people it seems natural and inevitable that a man should adopt the totem and magico-religious practices of his mother rather than his father.

And it is bad enough that my opinions should be formed according to those of Lord Beaverbrook or Lord Southwood, but even worse that they should be formed by the late Sir Henry X, a food adulterator who left large sums to the Wesleyans out of a very natural and justifiable fear of hell-fire; or Mme Y, an opera singer with a whale of a past, who endowed a Catholic church for a similar reason. One of the great benefits of Socialism is that churches, like cinemas, are paid for by their audiences and not subsidized out of legacies. The living generations are not subject to the 'dead hand' of the past. The churches therefore cease to function when nobody wants them.

We should strive to establish in this country the legal position laid down in Article 124 of the new Soviet Constitution, by which every citizen is guaranteed freedom of religious worship and anti-religious propaganda. It may be that this constitutional right is not always fully enjoyed in Russia; but it does not even exist in England.

We should realize that religious beliefs persist for economic and political reasons in the face of valid intel-

lectual arguments, and that it is futile to expect that Rationalism will triumph if it uses only intellectual weapons. We cannot neglect these weapons. On the contrary, we must use them as fully as we are allowed to. For, if we do not, the decay of religion will lead, not to Rationalism, but to mere indifference, and will furnish a soil for doctrines quite as irrational as any religious creeds, as has been the case in Germany.

But I question whether most Rationalists enquire with sufficient care and thoroughness into the social and economic basis of religion in their own countries. This is just as important a question as the date of St. John's Gospel, and one on which it is almost equally difficult to arrive at the facts, because we take so much in our social environment for granted. I hope that this article may be of some value in helping its readers towards an objective point of view.

THE DUTIES OF A CITIZEN OF A CRIMINAL STATE

THE present * policy of the National Government raises an extremely interesting moral problem which every democrat will, I fear, have to face in the near future. Until recently the vast majority of democrats in this country took it for granted that their actions should be within the law. Even where a law is unjust, there is a good case for obeying it. Not only will a breach land individual law-breakers in jail, but it will open the way for further breaches, and an epoch of violence is likely to end in the extinction of such liberties as we now possess.

This argument is very strong provided two conditions are fulfilled. In the first place, a constitutional means for altering the unjust law must exist; and in the second, the existing laws must be respected by the government.

The second of these conditions is no longer fulfilled to-day. Paragraph 1 of Article 16 of the Covenant of the League reads as follows:

Should any member of the league resort to war in disregard of its covenants under articles 12, 13, or 15, it shall ipso facto be deemed to have committed an act of war against all other members of the league, which hereby undertakes immediately to subject it to the severance of all trade or financial relations, the prohibition of all intercourse between their nationals and the nationals of the covenant-breaking State and the prevention of all financial, commercial, or

personal intercourse between the nationals of the covenant-breaking State and the nationals of any other State, whether a member of the league or not.

It is an indisputable fact that our existing government has repeatedly and deliberately violated this law, and that as a result not only has the existing situation in China, Spain, Abyssinia, and Austria arisen, but a considerable number of British sailors, both of the Royal Navy and the Mercantile Marine, have lost their lives.

Rightly and naturally, the law-abiding people of this country attempted to use constitutional means to see that the Covenant was enforced. At the last general election they secured a solemn pledge from the National Government that its foreign policy would be based on the Covenant. This pledge was immediately broken, and is now being broken.

It must be realized that, from the point of view of international law, it is actually illegal to buy Japanese goods, or to take a holiday in Italy. Dockers who refuse to load Japanese ships are keeping the law. Their employers are violating it. In reply to a recent question in the House of Commons the Minister of Labour referred to the suggestion (not made by a communist) that dockers who keep the law of nations should be given unemployment benefit whilst out of work in consequence, as communist propaganda.

Whilst communists will doubtless thank Mr. Brown for this free advertisement, it is of the utmost importance to liberalism and labour that a respect for international law translated into action should become liberal and labour policy, as well as communist policy, immediately.

Now it is very probable that a British Court of Law

might decide that the dockers' action was illegal. I do not know whether a witness in a court would even be permitted to quote the Covenant. This simple example shows that a respect for law may lead to illegality.

It is unfortunate that this should be so. But the attempt to enforce international law by legal methods was made at the last general election and failed. When Governments break the law, honest men become revolutionaries. We must, I believe, look forward to a period during which we shall only be able effectively to show our respect for international law by violating the civil and perhaps the criminal law of England. This is not a call to anarchism. '*Teneor patriae nec legibus ullis*' has been an out-of-date slogan since the rising density of human populations due to the invention of agriculture in the neolithic period made organized society a necessity. It is not a call to acts of individual violence, which are usually futile, and often demoralizing to the actor.

It is a call to support any organization which is acting so as to enforce respect for international law and to turn out the present government. And the extent of this support should depend on the intensity of the action which that organization is taking, not on its respect or otherwise for legal forms.

Active support for international law may lead to imprisonment or (as in the case of John Cornford) to death. This cannot be helped. The late Professor Housman's line

Let us endure an hour and see injustice done

is regrettably popular in Cambridge. Professor Housman endured for over seventy years. Byron did not. There is much to be said for enduring only half an hour, during

which one fights injustice. The same attitude was common in German and Austrian universities during the last twenty years. The present position of those universities is a matter of common knowledge.

Another type of criticism from within the Democratic Movement is well put by Mr. Warren in the January number of the *Democrat*.* It is that democracy, like charity, begins at home. True, but governmental illegality begins abroad and spreads homeward. Let me take two simple examples from English history. Throughout the imperialist expansion of Britain during the eighteenth century the seamen needed for this purpose were obtained by the pressgang, that is to say, by kidnapping. If they attempted later to assert their liberties they were flogged or hanged. In 1914 in order to preserve English domination in Ireland the Conservatives imported rifles from Germany with a view to civil war.

If we do not protest by deeds as well as words against governmental crime abroad, we shall have to face it out at home. And it will serve us absolutely right.

* In which this article appeared later in the year.

THE NEXT THIRTY-THREE YEARS*

WHAT is going to happen in the second third of the twentieth century? I do not know, and very likely I am much happier for not knowing. Even although it is no longer customary to stone prophets, prophecy is a ticklish job. I have exercised this occupation off and on since the War, and have often been wrong. Still I can take credit for prophesying in 1919 the decay of agriculture as a result of a world-wide over-production of food, so I may spot a few winners in this article.

To Englishmen in 1966, the first third of the century, including the first world war, will look like a golden age of peace and stability. Every year the application of science to industry and agriculture will make production easier, and so tend to lower prices and increase unemployment. Governments and trusts will try to fight the menace of plenty by destroying crops and shutting down superfluous factories, instead of keeping production busy by seeing that every citizen is properly fed, clothed, and housed. Our own will compromise, giving with one hand and taking with the other, and I do not expect to see a great fall in our standard of living until a British Hitler arrives on the scene.

Meanwhile one nation, Russia, will be continuously increasing its production. By 1950 the Russians will have reached a fairly high standard. The fourth five-year plan will deal with the organization of leisure. Instead of

* Printed in the *Daily Express* in 1933.

permitting unemployment they propose to plan the leisure of their workers in sport, education, and travel. If they succeed that will spell the end of capitalism, unless a capitalist nation has meanwhile succeeded in doing the same job better. Britain has had twelve years of unemployment without tackling this problem. So if Roosevelt does not get the wheels of American industry running in the next two years, we may expect to see a largely Russianized world by 1966, even if the Japanese succeed in conquering Eastern Asia.

The general decay of our economic system will show itself in revolutions, and ultimately wars. The object of each side will be to goad the enemy civilians into revolutions, and some, at least, of the defeated nations will take to Communism. I don't believe that another war would end civilization. I would sooner see a couple of million average British civilians killed by bombs and gas in a month or two than a million of our best men killed over a period of four years. And a disaster of that kind might induce the survivors to organize our national life.

I may be wrong in the last paragraph. But I am certainly right in this one. By 1940 the population of Britain will have begun to fall, and by 1966 it will have fallen very considerably, even if the fertility of women stays at its present level. The populations of most other European states will be down, and those of the U.S.A., Australia and New Zealand will be stationary or falling, though Canada may still be growing slightly. On the other hand, Russia and Japan are growing very rapidly, and Russia at least will do so for a generation to come.

Some states will copy Germany, and try to drive women back to motherhood by squeezing them out of industry. This will fail as it has failed in Italy. But by

1966 I hope that England will have realized that parenthood is a public service and should be paid as such.

Even if we then begin to restore our population, it will be too late. By 1966 Britain will be a second-rate power, full of old men and women, but with very few children. We shall probably have more clerks, shop-keepers, and unemployables, and fewer skilled workers. This will be our punishment for having thought in terms of money, not of men and goods. In times of peace life will be tolerable. There will be new amusements for those who can afford them, a good deal more flying, perfected television, free broadcasts and talkies for the unemployed, a good deal of flag-wagging. Our literature will largely be concerned with the romantic nineteenth century. But there will be a general feeling among intelligent people that the glory has departed, and life is rather a poor game.

Now for the other side of the picture.

Somewhere in the world, by 1966, I think there will be a scientific state. Here is a picture of life in a scientific Britain, though I doubt if Britain will lead the way in the twentieth century as she did in the nineteenth. Every child, from nine months before its birth, is under the care of the health service, for motherhood is a well-paid and honoured profession, but a profession with rules like any other. At every stage of education the ablest children are picked out for different occupations. At twelve years children are already working for two hours a day in industry or agriculture, and by twenty most people are at work in a factory or mechanized farm for a thirty-hour week, with three months' annual holiday, which is generally spent in the great holiday areas along the coasts, and in Wales, the Lakes and the Scottish Highlands. The

minimum real wage of an adult corresponds to about three pounds a week to-day, with one pound a week per child.

Everyone is medically inspected twice a year, by one of the two hundred thousand doctors, and most diseases are prevented. Measles and common colds are isolated like small-pox to-day, and many people go through life till seventy without a day's illness. In a hospital for heart disease you will see patients whose hearts have been removed for repairs, while the pump by the bedside takes their place temporarily, and the pneumonia patient will breathe with artificial lungs while his own are inflamed.

There is no more unemployment. A labour-saving invention means an extra day's holiday, or the release of more labour for teaching and amusement. Most people live in large blocks of flats, with meals in a restaurant or automatically served from a mechanized kitchen. There is far more liberty than to-day. Most of our restrictions are the result of prejudices with no scientific basis. Provided you do not interfere with production or spread disease, your spare time is your own. Politics are mainly a matter of finding out what people actually want, and supplying it, whether it is more dog-racing, more silk stockings, or more symphony concerts. Religion is there for those who want it, but science and religion do not mix very well, and most people are members of no religion.

We grow about half our own food, and with three years' reserve of wheat and machinery available for converting wood-pulp and straw into starch and sugar we shall be able to support ourselves in case of war. Our cities are built largely bomb-proof and gas-proof, and we

have a million trained air-pilots with ten million skilled mechanics behind them. We shall have nothing to gain from war, but a less organized state will have everything to lose by attacking us. Scientific research is the growing-point of our national life. Besides the quarter million professional scientists, who are mostly also teachers or attached to an industry, many people spend their holidays in a laboratory, and millions have adopted animal or plant breeding as their hobby. One great voluntary organization is exploring the depths of the earth, and has just got down fifteen miles. Another is planning the first rocket voyage to the moon.

All these things are possible to a nation which will organize itself to use the means which science has put at its disposal. They may come to pass in Britain or one of the Dominions. And if they do not it will be our fault.

THE MARXIST PHILOSOPHY *

LORD HALDANE was a Hegelian through most of his life. And in his last years, as a member of the Labour Party, he was a moderate, but I think a convinced socialist. It is therefore fitting that a lecture in his memory should describe the philosophy which is largely based on that of Hegel, and one of whose main features is an account of the nature of the transition from capitalism to socialism. In the last conversation which I held with him, a few months before his death, I mentioned the deep impression which had been made upon me by the prevalence of this philosophy in the Soviet Union, and the successful attempts which were being made to apply it in different fields, including my own field of biology. He answered that he was following its development, and I understood that he approved of it as a Hegelian, but condemned it as an idealist.

Like many other people, I had been unaware until then of the very existence of Marxism as a philosophy. I knew of Marx as an economist and a political organizer. I even knew something of the doctrine of historical materialism. But I had no idea that Marxist principles were applicable outside the social sphere, that an astronomer, a chemist, or a biologist might find them valuable aids to research. Unfortunately Lord Haldane died before I could take the measure of his agreement and disagreement with these principles.

* Delivered at Birkbeck College, London, in 1938, as the annual Haldane Memorial Lecture. My late uncle, Lord Haldane, had done much for this College.

At that time I merely took note of Marxism as one philosophy among many. It was not until I read Engels' books *Ludwig Feuerbach and the outcome of classical German philosophy*, and *Herr Eugen Dühring's revolution in science*, generally known as *Anti-Dühring*, that I found that in his interpretation of science, Engels was far ahead of his time. Had these books been familiar to my contemporaries it was clear that we should have found it much easier to accept relativity and quantum theory, that tautomerism would have seemed an obvious hypothesis to organic chemists, and that biologists would have seen that the dilemma of mechanism and vitalism was a false dilemma.

Nevertheless, I found Engels' materialism a difficulty, and above all, I was unable to accept the political implications of the theory, which ran counter not only to the views of conservatives and liberals, but to the socialist theories current in the Labour Party. Indeed, these implications, as developed, for example by Lenin, in *State and Revolution*, are, if anything, more paradoxical to a socialist who is inclined to exalt the State and to aim at making it the owner of all productive resources, than to a supporter of capitalism.

But a group of facts obtruded itself upon my notice. I found that the political and economic life of Britain was becoming riddled with internal contradictions. At a time when national self-sufficiency in food might be of vital importance, farmers were fined for growing too many potatoes. At a time when two European statesmen were openly claiming portions of the British Empire, I found the Conservative leaders in Britain abrogating the principles of international law and refusing to carry out their obligations under it, in such a way as to favour the states-

men in question. I found the Conservative Members of Parliament greeting with laughter and cheers the news that British ships had been captured.

And I observed similar phenomena in the moral field. The growth of corruption in public life was obvious, even if only rarely, as in the case of Mr. Thomas, did a lapse from nineteenth-century standards of honesty receive publicity. The events leading to the abdication of King Edward VIII showed how hollow were the phrases and how artificial the sentiments which supported so important an institution as the monarchy. It is true that few among our political leaders possess the intellectual honesty of Captain Balfour, the Under-Secretary for Air, who wrote, in a letter to *The Times* * on British foreign policy:

This conclusion may be right morally or it may be wrong. It may be said to be breaking pledges made by politicians in the past, or it may be said that we are not bound by any pledges. But none of this matters.

Nevertheless, it was clear that in practice the moral standards to which the British ruling class for a century or more had rendered complete service in word and a good deal in deed, had become obsolete.

And this was not, as might have been supposed, part of a general decay of morality. Our prisons were being emptied. Drunkenness had enormously declined during my own lifetime. The average man and woman had become kindlier and I think juster, if perhaps a little less honest. The decay of religion could hardly be blamed, when Lord Halifax lectured to the League of Nations on

* 21st March, 1938.

the unpractical character of moral ideals, and the Pope blessed the bombers of Barcelona.

In fact, the situation did not make sense, from my existing point of view. A realization of such facts has driven one group of intellectuals into a belief that civilization is doomed, whilst others call for a return to pre-scientific thought and practice. The latter solution seems to me particularly futile.

*‘μόνον γὰρ αὐτοῦ καὶ θεὸς στερίσκεται,
ἀγένητα ποιεῖν ἅσθ’ ἂν ᾗ πεπραγμένα.’**

(Even God cannot abolish historical fact.) If we go back to a medieval or earlier type of civilization it will be through disaster and not through Erewhonian planning.

But from a Marxist point of view the social phenomena of our day are intelligible. A number of them had been predicted in some detail by Marxist writers, though often with too short a time-scale.

And, though unpleasant, they are encouraging. In fact, Marxists are the only intelligent people who preserve their grandparents' belief in progress. Not of course in gradual and orderly progress, but in progress where in developing communities epochs of slow advance are punctuated by heroic ages like the present in which a new social order is brought to birth. In this birth certain desirable cultural features of the older civilization may be lost unless special efforts are made to preserve them by those who understand the nature of the process.

As a result of my scientific and political experience I had to accept Marxism as the best available philosophy. This acceptance does not mean that I think Marx never made a mistake. Of course he did. So did Newton,

* Agathon.

Linnaeus, Dalton, Darwin, and every other great man on whose general principles I rely in theory and in practice. Nor do Marxists regard Marxism as a final and unalterable system. At best it is the most satisfactory philosophy which was produced in the nineteenth century. It could not have been produced earlier. It will doubtless be improved later. But Marxists see no reason why it should be completely superseded any more than Newton's cosmology has been superseded by Einstein or Dalton's atomism by Rutherford.

Before sketching this philosophy I should like to make a preliminary apology. I am in no sense an expert on Marxism. There are others far better qualified than myself to give this lecture. Indeed, I have only undertaken the task because of the extraordinary statements which are made on the subject by otherwise well-informed people. For example, it is commonly stated that Marxism exalts the State as against the individual, that it preaches fatalism, and that it regards man as the slave of economic forces. We shall see later how far these statements are from the truth.

The Marxist philosophy is called dialectical materialism. It traces its origin on the one hand to the mechanical materialism of the French eighteenth-century philosophers such as Diderot, and on the other to the dialectical idealism of Hegel. Feuerbach was the first to attempt a synthesis of these apparently very disparate tendencies. But Engels, while acknowledging his debt to Feuerbach, pointed out the inadequate and inconsistent character of much of his writings. Marx' philosophical synthesis was largely contained in manuscript notes, incidental remarks in his political and economic writings, and in verbal teaching. Engels was more systematic, but he too refused

to dissociate philosophy from practical activities by writing a textbook.

Because, like Plato and many other Greek philosophers, they were deeply concerned with the practical results of their theories, Marx and Engels are difficult reading for a student of philosophy who wishes to describe their system among others. This has led, on the one hand to a neglect of their views by most teachers of philosophy in Britain, for which there are also other reasons, and on the other, to a need for further expositions of some parts of it, of which Lenin's *'Materialism and Empirio-criticism'* is particularly valuable.

There is, however, another reason for their failure to cover certain fields which few systematic philosophers have neglected. They had too great a respect for science, and they realized fully that Hegel's Philosophy of Nature had failed because he attempted to give answers based on pure reason to questions which could only be solved by observation and experiment. Thus while they were convinced that as an historical fact matter existed before mind, they did not embark on any detailed speculations as to how mind arose. This was not because they regarded it as an insoluble problem but because the data from evolutionary history and cerebral physiology were not (and indeed are not yet) available.

Marx had intended to be a philosopher, and was awarded a doctorate for a thesis on Epicurus. He abandoned an academic career because the Prussian Government dismissed men of less radical views than his own. It is amusing but futile to speculate on what would have been his intellectual output had he been born in a more liberal state.

Dialectical materialism is a whole. In an attempted

presentation it must be dissected into apparently separate principles, and thus lose its unity. I should like to emphasize that one can only learn its principles and practice by applying it to a set of facts of which one has detailed knowledge, whether they be concerned with the development of mathematics, the genetics of insect populations, or the relief of unemployment. For this reason a formal and abstract account can give no idea of its power as a method.

To begin with, Marxists acknowledge the unity of theory and practice, but the primacy of practice over theory. They hold that academic philosophies have been largely futile because their authors did not test them on the hard touchstone of action. Indeed many of them tried to avoid practical activity so far as possible. But Marx wrote * 'Other philosophers have interpreted the world. The point is to change it.' And as a Marxist must be prepared at any moment to stake his life on the truth of his philosophy, it is natural that he attaches a greater importance to practice than does the metaphysician. In the same way the physicist who proposes to test his theories in an actual aeroplane flight keeps closer to hard facts than the theorist of the expanding universe!

By materialism is meant the acknowledgment of the temporal priority of matter over mind, and the belief that there are unperceived events. The word is not taken to imply the unreality or 'lesser reality' of mind, as compared with matter, or the theory that either man or the universe are mere machines. Nor does it imply that nature is built up out of eternal bricks. On the contrary, at a time when atomism appeared to be triumphant, Engels insisted that reality consisted of processes, not

* Theses on Feuerbach.

things. He would certainly have welcomed the cosmological theories of Milne* and Dirac,* according to which even the laws of nature change. For example, according to Milne, the wave-length of a spectral line, measured in terms of a material rod, is gradually diminishing; and in relation to the day or year, chemical processes are speeding up.

What sort of properties has nature, or matter? It is in constant flux. No one can cross the same stream twice, as Heraclitus, to whom Marx and Engels acknowledged their debt, put it. And it embodies the unity of opposites. Plato saw that a body was at once large and small, hard and soft, and concluded that size and hardness were real, but matter was unreal. If we have resolved Plato's contradictions, or at least become accustomed to them, we are confronted to-day with still stranger contradictions, such as the fact that matter and light combine properties appropriate to particles with others appropriate to systems of waves. I do not think that there is any choice between denying the reality of matter and admitting the unity of opposites.

If we do so we find our path smoothed in all branches of science. We no longer ask, 'Is the organism a whole or an aggregate of parts?' We ask, 'How much of a whole is this particular organism at this particular time?' It then becomes clear that a man is not a complete whole. For example, two men of the same group can exchange blood. But he is more of a whole than a flat-worm or a primrose. For both these can be cut in two in such a way that both halves will live; and a man cannot. We note that in an animal or plant anabolism, or building up of tissue, is united with catabolism, or breakdown. One

* *Proc. Roy. Soc., A*, 1938.

may predominate, as in a growing or starving organism. But in the most highly developed animals, such as adult mammals and insects, they are very evenly balanced.

We are not surprised when Freud tells us that instincts making for death are as real and important in the human mind as those making for life, even though we may not accept the whole Freudian psychology. In the state we find the same conflict between classes which, according to Marx, is part of its very nature. Only in relatively few cases can this unity of opposites be regarded as a mere equilibrium. If, for example, I say that John Smith is a man, I assert the unity in him, of the particular, John Smith, and the universal, man. This cannot in any way be regarded as an equilibrium.

Now in Hegel's philosophy the unity of opposites was treated idealistically. The categories were supposed to have a timeless existence, and to be combined in various ways in the phenomenal world. Nature was explained as the development of the absolute idea. The principles of change were called dialectical because they were exemplified in dialectical thought. And Hegel believed that nature mirrored thought. Marx on the other hand went back to the common-sense view that thought and other mental processes mirror nature with different degrees of exactitude. Of two similar things, of which one is the copy of the other, the one which was there first is the original. And Darwin's work left Marx with no doubt that nature was in existence before mind. On the other hand, if the dialectical principles which govern thought are images of natural principles we must give up the theory that nature merely consists of moving particles. Metaphysics is an illusion, in the sense that there is nothing beyond nature; but nature is infinitely more

complex than the mechanistic materialists thought. It is clear that this philosophy encourages a scientific approach to all problems without in any serious way limiting the kinds of explanation open to the scientist.

Another fundamental dialectical principle is what Hegel called the transformation of quantity into quality. Marx * interpreted this rather obscure phrase as follows: 'Here as in natural science, is verified the correctness of the law discovered by Hegel in his "Logic" that merely quantitative changes beyond a certain point pass into qualitative differences.' Classical examples are the sudden changes of state which take place when, for example, water is boiled or frozen, and the changes which occur when we pass along a homologous series such as the paraffins (C_nH_{2n+2}). Throughout the nineteenth century scientists tried to show that discontinuous or qualitative change was more or less illusory. The mathematicians worked with continuous variables. The physicists treated electricity as an infinitely divisible fluid, and believed that a rotating body could have any angular velocity out of a continuous range. Darwin and the biometric school believed in the continuous variation of living organisms.

Twentieth-century physics are dominated by the quantum theory, which is perhaps the most fundamental form of the transformation of quantity into quality. If an electron could circulate round an atomic nucleus with any angular momentum the rigidity of bodies and the sharpness of spectral lines would be inexplicable. They become intelligible and predictable because only certain angular momenta are possible. The attempt to explain the boiling of water and other changes of state in terms of

* *Capital*, vol. I, p. 336 (Kerr edition).

the classical physics has failed. We now speak of discontinuous changes of state in single molecules or atoms, which change their properties when they absorb energy in certain definite amounts. Attempts to explain this fact in terms of other physical principles have met with little success. And few biologists believe in absolutely continuous variation.

The passage of quantity into quality is familiar to students of Aristotle's ethics. Aristotle said that a coward took too few risks, a rash man too many, a brave man an intermediate amount. In economics Marx illustrated it by the fact that a small amount of money cannot function as capital, whilst a large amount can, and by other examples.

Perhaps the most characteristically Hegelian principle in Marxism is that of the negation of the negation as a fundamental process in development. Let us take a characteristic example from psychology and ethics. A baby, after it has made its first, and perhaps most difficult, adjustments to the world, may develop into a 'good' child, which always obeys its parents, is never late for school, and never breaks any rules. Such a child is in the state which Hegel described as innocence, a negative condition which is a source of alarm to wise parents. They know very well that if it is to develop a positive character it must transgress rules from time to time, and be punished for so doing. And it must have temptations and learn to resist them, or at least some of them. It must pass through a stage of guilt, the negation of innocence, before it can attain to virtue.

This principle is one of the main sources of progress in mathematics. We must first dare to break a rule. For example, in order that all quadratic equations should be

soluble, complex numbers were invented, which violated the rules of ordinary arithmetic. For instance, the square of such a number might be negative. When the laws of arithmetic had been recast so as to allow of such numbers, a new stage of mathematics, based on the theory of the complex variable, became possible.

Sometimes a long time elapsed before the process was completed. Newton and Leibniz in the seventeenth century dared to break some of the laws of mathematics by introducing infinitesimals, and thus invented the differential calculus. It was only in the nineteenth century that Weierstrass, Cantor, and others gave a formal justification for this step, and a satisfactory theory of differentiation arose. In the same way Fourier violated a number of rules when he introduced harmonic analysis, and it was not till much later that Lebesgue provided a rigorous theory, which led to further progress.

Marx used this principle to illustrate economic progress. In the Middle Ages almost every skilled workman owned his tools, and the yeomen farmers at any rate owned the land on which they worked in England, as peasants do in many parts of Europe to-day. But the workers were expropriated from the means of production, sometimes by force, as in the case of land enclosures; but generally because capitalistic manufacture and agriculture based on a widespread division of labour, were more efficient than the individualistic forms. However, capitalism is now developing its own internal contradictions. Cyclical disturbances are increasing in intensity. And monopolism is leading to the restriction of production. When this breakdown becomes sufficiently severe it leads to socialism, in which the workers once more own the means of production, though no longer,

save in very rare cases, individually. The negation is negated; the expropriators are expropriated.

The refusal to recognize this principle has led to great difficulties in understanding evolution. Darwin believed that evolution occurred because in any species the majority of individuals died before they could reproduce, and their death was a selective process. Many people rejected the idea that mere killing could cause increased perfection. Actually Darwin's principle can be extended. A perfect organism could not evolve. It must, to begin with, be mortal. If it reproduced itself exactly it would gradually become out of date. On the contrary a real organism reproduces itself inexactly, thus giving the possibilities of variation. Most of the deviations from the normal are harmful, and natural selection is mainly concerned in eliminating them. This is only possible when there is an overproduction of offspring. All these conditions are only prerequisites for evolution, and all of them are harmful to the individual.

This state of affairs is intelligible neither to the subjective idealist or Panglossist who thinks that all is for the best in the best of all possible worlds, nor yet to the mechanistic materialist who does not realize that progress normally occurs through conflict. It is entirely intelligible to any Marxist who has digested what Engels had to say about evil.

'One believes one has said something great,' Hegel remarks, 'if one says that man is naturally good. But one forgets that one says something far greater when one says man is naturally evil.' According to Hegel, evil is the form in which the motive force of historical development presents itself. This indeed contains the two-fold significance that while, on the one hand, each new advance appears as a sacrilege against things hal-

lowed, as a rebellion against conditions which, however old and moribund, have still been sanctioned by custom; on the other hand it is precisely the wicked passions of men, greed and lust for power, which since the emergence of class antagonisms, serve as levers of historical development.*

At this point, or earlier, a critic is likely to accuse Marxists of clandestine idealism. 'You are talking about contradictions in matter, whereas contradictions are mental phenomena. It was legitimate for Hegel to use dialectic, because he was an idealist. It is wrong for you to do so.' The Marxist replies that he has a good deal of confidence in the human mind. He thinks it is so intimately dependent on matter that it really can mirror its behaviour. And he points out that the union of opposites, for example, is very often a hard physical fact. An electron is completely hard in the sense of being indivisible, a gas completely soft in the sense that it opposes no resistance to division, if this is done slowly enough. Hardness and softness are united in ordinary solids. Acetic acid is an acid, ammonia is a base; glycine, which is one of the essential constituents of proteins, is both an acid and a base at once, and therefore has some new properties.

The Marxist theory of truth is straightforward. Absolute truth, except perhaps on trivial matters, is never reached, but continually approached.

The question whether objective truth can be attributed to human thinking is not a question of theory but a practical question. In practice men must prove the truth, i.e. the reality and power, the this-sidedness of his thinking. The dispute over the reality or non-reality of thinking which is isolated from practice is a purely scholastic question.†

* Engels in *Feuerbach*.

† Marx's theses on Feuerbach.

But since Marxists believe in the existence of the world apart from our minds, Marxism has little affinity with pragmatism.

Dialectical materialism as applied to human society is called historical materialism. This doctrine does not deny the freedom of the human will or assert that man is the slave of economic processes. But it states that the most fundamental features of human societies with a class structure are determined by their productive processes, using the word production in its broadest sense, to include transport and other processes in which human labour adds to the value of goods. I do not think that Marx or Engels thought that this principle held to anything like the same degree in primitive societies with a slightly developed class structure.

The alternative theory is that the economic structure of a society is determined by its political structure, the latter being based on consent or on violence. Marx and Engels were equally critical of Rousseau's theory of the social contract, and the anarchist theory that property is theft. They also criticized those of their disciples who attempted to give an economic interpretation of every detail of history. They pointed out the obvious fact that institutions possess a very great inertia, and continue to function and even to develop long after the economic processes which originally determined them are finished. They also admitted the importance of what from the historical point of view are accidents, such as the births or deaths of great men, but added that on the whole these accidents cancelled one another out, and did not affect the general course of history.

Here we must say a few words about the Marxist theory of the freedom of the will. Engels quotes with

approval Hegel's saying, adopted, I think, from Spinoza, that freedom is the recognition of necessity. Thus we discover a scientific law, for example that people who drink water polluted with *Bacillus typhosus* very often develop typhoid fever. This at once opens the possibility of circumventing it. For we can escape infection by boiling our water or getting immunized. So freedom is continually negating its own negation. Throughout history men have struggled against the results of economic laws. They have never been completely their slaves. But the economic system has determined the form of the struggle.

When, however, we recognize the necessity, that is to say adopt historical materialism, we become far freer. We attempt consciously to remedy not merely this or that evil, such as slums, malnutrition, or war, which results from the operation of economic laws, but to alter the whole economic structure of society so as to make it classless. Thus so far from proclaiming man's slavery to economic laws, Marxism shows how his existing partial slavery to them can be overcome.

A philosophy of history can never be proved *a priori*; it can only be tested by its applicability to particular events, and particularly by examining its powers of prediction. For this reason few of Marx' writings are more suitable for those who are genuinely anxious to test the validity of his theories than those, such as *The Eighteenth Brumaire of Napoleon III*, in which he analysed the events of his own age. I do not suggest that he never made a mistake. He did make mistakes, but he made vastly fewer than any of his contemporary writers known to me who did more than chronicle the events of their time.

The most comprehensive attempt to apply this philosophy to human existence as a whole is Engels' *The Origin of the Family, Private Property, and the State*. Of course, this would have to be re-written to some extent in the light of increased modern knowledge of prehistoric technique and of existing or recently dead primitive societies. Many people doubt Engels' view that sexual relations between exogamous groups were ever promiscuous. However, anthropologists to-day would, I think, accept his statement that at a certain stage of development the normal organization of a primitive tribe is as follows. The tribe is divided into several exogamous groups, or *gentes*, membership of which is matrilineal. The *gens* is the effective unit for many economic and other purposes. Such property as cannot be carried about, for example gardens, may be assigned to individuals for life, but ultimately revert to the *gens*. There is strong evidence that this system existed shortly before the dawn of history in ancient Greece and Italy. It is probably a universal step in human development, except where a people in a still earlier stage has been conquered before it could reach this one.

As productive technique improves, and particularly when animals others than dogs are domesticated, the *gens* tends to become patrilineal. A man can now leave his property to his sons, instead of his sisters' sons. The nature of the family changes radically. It becomes patriarchal and accumulates property, such as houses and herds, though neither may at first be individual property. Thus class-divisions based on economic differences arise, and an organization is needed to perpetuate them; to keep order in conservative terminology, to oppress the poor in radical terminology.

For Marxists the state, with its police, standing army, tax collectors, and so on, is a parasite on the community, and a product of the class struggle. There is no state in the primitive classless societies. This theory appears paradoxical to us to-day, because, whether socialists or not, we are mostly conscious or unconscious state-worshippers, who confuse love of our country with reverence for the state. In our grandparents' time it was far easier of acceptance. Not only did radicals inveigh against state parasitism, but so conservative a writer as Cardinal Newman * wrote, 'In a civil polity the State exists and endures by means of rivalry and collision, the encroachments and defeats of its constituent parts.'

As long as there is a class-struggle there will be a state, and when the class struggle comes to an end the state will wither away. It is useless for the anarchists to try to abolish the state. It is needed in the early stages of socialism while the class struggle continues. On the other hand, it will be necessary, in order to achieve socialism, to scrap the existing state organization pretty completely, and to substitute one which is as intimately in touch with the workers as the existing state organization is with the well to do.

Marx is probably best known for his economic analysis of the rise of capitalism, its nature, and its internal contradictions. His most striking single contribution to economic theory is his theory of surplus value. I have no intention, if I had the power, of expounding his economics. I would only point out that in so far as he predicted that capitalism would work progressively worse, his prediction has been verified. On the other hand, he did not give a detailed prediction of the present stage

* *Apologia pro vita sua*, p. 391. London, 1864.

of economic development, which is characterized by monopolism, imperialism, and finance capitalism. One of its most striking features is the existence of massive unemployment even during periods of comparative prosperity. This stage has been analysed particularly by Lenin in *Imperialism*.

I would add that, if *Capital* is Marx' greatest work, it is also his most difficult, and that so far from its being familiar, it has never even been published completely in England, the only full edition in our language being printed in Chicago.* It is certainly one of the last, rather than the first, works which anyone should read who wishes to understand Marxism. While he exposed the evils and injustices of contemporary capitalism, he did not think that it would perish primarily because it was unjust, but because it was inefficient, though, of course, the injustices would furnish motives for its overthrow.

Granted that it was possible to achieve an economic system combining on the one hand large scale and therefore efficient production, and on the other the abolition of a class living wholly or mainly on the surplus value created by the labour of others, how was the transition likely to be achieved? Fourier, Owen, and others thought that a scheme could be worked out in considerable detail, and then adopted by general agreement. Marx, although admitting his debt to these thinkers, characterized them as Utopian rather than scientific socialists, because they did not see how largely political and other ideas are determined by the economic structure of society rather than by reasoning. The determination is not direct. One does not say 'this is right and reasonable because it is

* A London edition has since been printed.

to my advantage or that of my class'. On the contrary, the motivation is largely unconscious, and Engels' brief account of unconscious motivation anticipates that of Freud and other modern psychologists.

The Marxist sees how capitalism develops self-contradictions not merely in the economic but in the intellectual field. He notices how (to take a very simple example) the British government at one and the same time does its best to protect British capital invested abroad, and to prevent by means of tariffs the inevitable result of that investment, an unfavourable trade balance; how it is inevitably torn between contradictory interests in any attempt at planning. He sees how these contradictions are multiplied under fascism, where the same government clamours for colonies on the ground of overcrowding and encourages large families, or boasts of the importance of racial purity whilst attempting by conquest to incorporate members of different stocks to its own. To the Marxist these are not so much examples of conscious hypocrisy as of muddled thinking which is the result of muddled economics. For as Engels saw, a large number of people may will the same thing, but the resultant of all their wills may be something quite different.

Given such facts, the truth of Marxism is very far from assuring its acceptance. Marx thought that socialism could not be achieved by legal means in any great nation except Britain and America, and even there he thought a 'pro-slavery revolt', to use his own analogy, quite possible. Lenin thought that the social structure of Britain had so altered that any attempt to introduce socialism by constitutional means there would be opposed by violence. Thus a Marxist must be prepared for revolution, though in this country such a revolution

could only be one in defence of our existing rights. Lenin's statement * on the subject is perfectly clear.

The fundamental law of revolution, confirmed by all revolutions and particularly by all three Russian revolutions in the twentieth century, is as follows: it is not sufficient for revolution that the exploited and oppressed masses understand the impossibility of living in the old way and demand changes: for revolution it is necessary that the exploiters shall not be able to live and rule in the old way. Only when the 'lower classes' do not want the old and when the 'upper classes' cannot continue in the old way can the revolution be victorious.

This is, of course, well illustrated by the history of the English Revolutions of the seventeenth century, and there is a strong conservative sentiment behind every revolution. At the present moment revolutionary ideas are spreading rapidly † in Britain because the Government is violating international law, and many people believe that the ruling classes are prepared to break the laws of their own country as they did in Italy, Germany, and Spain. The Marxist analysis of the nature of the state shows why a state may be prepared to sacrifice its interests in the international field in order to preserve its class structure, and thus renders the existing political situation intelligible.

One of the commonest criticisms of Marxism is that it is a body of quasi-religious dogma which must be blindly accepted. 'Our theory is not a dogma but a guide to action, said Marx and Engels.' ‡ For this reason it is

* *Left Wing Communism.*

† In the week before this lecture was given over 600 Londoners joined the Communist Party.

‡ *Left Wing Communism.*

impossible to accept it without taking part in action. It presents very real difficulties to one who has been brought up in the metaphysical tradition. Yet a previous acquaintance with Spinoza, the French eighteenth-century materialists, and Hegel, is ultimately of great value to a Marxist. But it is not until one applies it to concrete problems that one realizes its power. I was fortunate enough to be educated in biology by my late father, whose views on biology were close enough to dialectical materialism to cause a Moscow radio speaker to recommend one of his books to British readers. And I have found Marxism of real value in the planning of biological research.

But great as is its value for science, it was primarily fashioned to allow political and economic events to be predicted and controlled. Here my own reaction to it has been like my reaction to organic chemistry. I could not wholeheartedly believe in the latter until I had not merely verified the feasibility of textbook experiments, but actually used it as a guide to action, and correctly predicted the properties of some hitherto uninvestigated substances. When on the other hand one accepts either organic chemistry or Marxism as part of one's daily thought, the world appears enormously richer in content and fuller of pattern. Just for this reason it is peculiarly difficult to expound Marxism unless one is sufficiently convinced of its validity to apply it in many different fields. This must be my excuse for trespassing on the professional philosopher's ground.

When a philosophy is daily assuming greater practical importance it is desirable that it should be presented to university students as part of their general education. Whether or not Marxism is true—and the course of

history will prove or disprove its validity—it is undoubtedly destined to play an increasingly important part in the history of the world in general and this country in particular during the next few years. And it is therefore a fitting subject for a lecture in honour of Lord Haldane, who combined philosophical theory with political practice, and made notable contributions to both.

WHAT I REQUIRE FROM LIFE

In Memoriam

MARGARET FULLER, a New England mystic, once said, 'I accept the universe.' To which Thomas Carlyle remarked, 'Gad, she'd better.' I have got to accept the universe as it is. I must not require the impossible, and I shall do harm rather than good if I try to imagine perfect beings in a perfect world. But given the world as it is, I can say what I may reasonably hope both for myself and for others.

I was born in a peaceful age, and in my youth I looked forward to a life of peace. Since 1914 I have been living in a heroic age, and I see no prospect of surviving into another epoch of peace and quiet. So I must try to make the best of the time in which I live. What do I ask for myself? I assume that I have food, water, clothes, and shelter.

First, work, and a decent wage for my work. Aristotle defined happiness, not as a sum of pleasures, but as unimpeded activity. I want work which is hard but interesting, work of which I can see the fruits. I am exceptionally lucky because I can choose my own work to a large extent. If I want a respite from science I can go and be a war correspondent, or write children's stories, or make political speeches.

So I enjoy a good deal of my second requirement, freedom, in fact vastly more than most people. But I want still more, particularly more freedom of speech. I should like to say and write what I think about Lord Blank's newspapers, Mr. Dash's pills, and Sir John

Asterisk's beer, all of which are poisonous. The law of libel prevents me from doing so.

I require health. I don't mind an occasional toothache or headache, or even an acute illness every seven years or so. But I want to be fit for work and enjoyment in the intervals, and to die when I can work no longer.

I require friendship. Particularly I require the friendship of my colleagues and comrades in scientific and political work. I want the society of equals who will criticize me, and whom I can criticize. I cannot be friends with a person whose orders I have to obey without criticism before or after, or with one who has to obey my orders in a similar way. And I find friendship with people much richer or poorer than myself very difficult.

These four things are general human needs. For myself I also demand adventure. Life without danger would be like beef without mustard. But since my life is useful it would be wrong to risk it for the mere sake of risk, as by mountaineering or motor racing. As a physiologist I can try experiments on myself, and I can also participate in wars and revolutions of which I approve. By the way, love of adventure does not mean love of thrills. I spent six weeks in Madrid during the recent siege. The only thrill that I got there was from reading Rimbaud's poetry. The satisfaction of adventure is something much more solid than a thrill.

There are other things which I desire, but do not demand. I like to have a room of my own with some books, good tobacco, a motor-car, and a daily bath. I should like to have a garden, a bathing-pool, a beach, or a river within easy reach. But I have not, and I bear up quite happily.

I am an exceptionally lucky person because I get a good deal of what I want, and can work actively for the rest. But most of my fellows do not enjoy what I regard as essential requirements. And I cannot be completely happy while they are unhappy.

I want to see every healthy man and woman on the planet at work. But everywhere outside the Soviet Union there is unemployment, though very little in Sweden. I am a socialist because unemployment, at least during times of depression, is an essential feature of capitalism. I want the workers to see the fruit of their own work not in profits for others, but in their own and their friends' well-being. My main personal complaint is that my work is not applied. I discover new biological facts, but no use is made of them, because although the community would benefit, no individuals would make profits from their application.

I want to see the workers controlling their conditions of work as I control my own to a considerable extent. Most work is dull, much of it is unhealthy and exhausting. This need not be the case, and I believe will not be after a few generations of democracy in industry. How pleasant work can be is shown by a simple fact. When we have time and money to spare, two of our favourite occupations are hunting and gardening, the work of our palaeolithic and neolithic ancestors respectively. I am a socialist because I want industry to be controlled by the workers. Freedom should begin in the workshop.

I want to see every man and woman as healthy as possible. This implies food, housing, and medical attendance of the quantity and quality which human biology demands and modern technique can supply.

I want to see the end of class subjection and sex sub-

jection. Only so will the equality which is the condition for fraternity be achieved. Since the main barriers between classes and the main reasons for the subjection of women are economic, I look to a revolution in the economic field for their end.

I am a socialist because I want to see my fellow men and women enjoying the advantages which I enjoy myself. I know that socialism will not confer all these advantages in an instant, but if I live to see capitalism overthrown and the workers in power through most of Europe I shall die happy.

Certain things are lacking in my list of requirements, notably peace and security. It is futile to require things which one is most unlikely to obtain. Fascism is a living reality, and fascism, as Hitler and Mussolini explicitly state, and prove by their actions, implies war. War is spreading at present. I sincerely hope that it will not spread over the world, as it spread in 1914 to 1917; but I do not look forward to perfect peace till fascism is dead.

I fully realize that peace and security are rightful aims, and that my own desire for violent adventure is probably merely an adaptation to the age in which I live. I am a child of my age, and all the worse for being one. I therefore demand security rather than adventure for others.

I have said nothing about many things which I desire to see, such as a spread of education, and an increasing application of scientific methods in all branches of life. From what I have seen in Russia and in Spain I do not doubt that these and other good things would follow almost automatically if our class distinctions were abolished.

To sum up, for myself I require food, warmth, work,

liberty, health, and friendship. For the society in which I live I require socialism.

Supplementary to my requirements of life are my requirements of death. Of all men whose deaths are recorded, I consider that Socrates' was the most enviable. He died for his convictions, when he could easily have survived by betraying them. He died at the age of about seventy, still in full possession of his faculties, but having completed all the work which he could reasonably hope to do. And he died laughing. His last words were a joke.

I do not require of death that I shall be as fortunate as Socrates. A death which fulfils all the three conditions of his is very rare. But if I can achieve even two of them I shall have done well, and though my friends may lament me, I trust that they will not pity me.

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